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CONCRETE BRIDGES ON THE ST. LOUIS & SAN FRANCISCO RY.

The improvements being made on the line of the St. Louis & San Francisco Ry. include the widening of the line entering St. Louis, and the replacement of some steel bridges with concrete arch bridges in connection with this work. The view, Fig. 1, shows a new bridge built at the second crossing of the Des Peres River, at Cheltenham, which is a St. Louis suburban station. This is a double track structure with four arches of 21 ft. span, and bench walls 7 ft. 6 ins. thick. The foundations are on solid rock. This has taken the place of a single-track plate girder deck bridge having two spans of 54 ft.

The drawing, Fig. 2, shows the third crossing of the same river at the suburban station of Lindenwood. This is a four-track structure with three arches of 36 ft. span and bench walls 15 ft. 6 ins. thick. Part of the foundations are on rock and part on piling driven to rock. This has taken the place of a deck steel structure having a pin-connected central span of 126 ft. and two approach spans of 66 ft.

FIG. 1. DOUBLE-TRACK CONCRETE BRIDGE AT CHELTENHAM, MO.; ST. LOUIS & SAN FRANCISCO RY.

Both these bridges are of plain concrete, without steel reinforcement; the reason given for this is that it is found that on this road reinforced concrete cannot be used economically, as it requires a saving of at least 50% of concrete to construct an arch of reinforced concrete on the same conditions as an arch of plain concrete. In building the four-track bridge, one half was built first (on the north side of the old bridge) and two tracks laid to carry the traffic; the old bridge was then removed, and the bridge completed for two additional tracks on the original alinement. These latter form the main tracks. This work amounted to about 5,000 cu. yds. of concrete, and cost approximately $4.80 per cu. yd., while the Cheltenham bridge cost about $4.60 per cu. yd. The concrete is made of "chats" or crushed ore from the lead mines of southwest Missouri and southeast Kansas, which contains a sufficient quantity of dust to avoid the necessity of mixing any sand with it. This material is considered a very valuable material for making concrete. All of the concrete was made in the proportion of 1 part Portland cement to 6 parts of chats.

The work was done under the direction of Mr. C. D. Purdon, M. Am. Soc. C. E., Engineer of Maintenance of Way; Mr. A. F. Geise is Engineer of Bridges and Buildings, and Mr. J. H. Kent was engineer in charge of the work.

SOME EXPERIMENTS WITH VENTILATING FANS.

By D. W. Taylor,* Naval Constructor, U. S. N.

Rotary fans attached to pipe systems for forced or mechanical ventilation were first fitted on United States vessels by Ericsson on his monitors. They have figured more or less on our naval vessels ever since, even upon the wooden vessels built in the seventies. Until about seven years ago steam fans were used. The earliest vessel to have a complete outfit of electric fans was the "Nashville," first commissioned in 1897. For five years or more all ventilating fans have been electrically driven. In the earlier vessels of the new Navy, built between 1885 and 1890, it was customary to fit a few large steam fans for ventilating living spaces, and these were so fitted with a system of flap valves that they could be used either as supply or exhaust fans. When such a system, after being run exhausting for some time, was changed to supply air, it blew into the living spaces an astonishing amount of dust which had accumulated in the pipes. At present, while both supply and exhaust systems are fitted, the tendency is to rely mainly on the former and use the latter only for such places as lavatories, water closets, dynamo rooms, steering engine rooms, etc. Probably under conditions on shipboard a supply system requires less power to move a given quantity of air. A distinct advantage is that with single piping fresh air is supplied positively. With an exhaust system the air which takes the place

*U. S. Navy Yard, Washington, D. C.

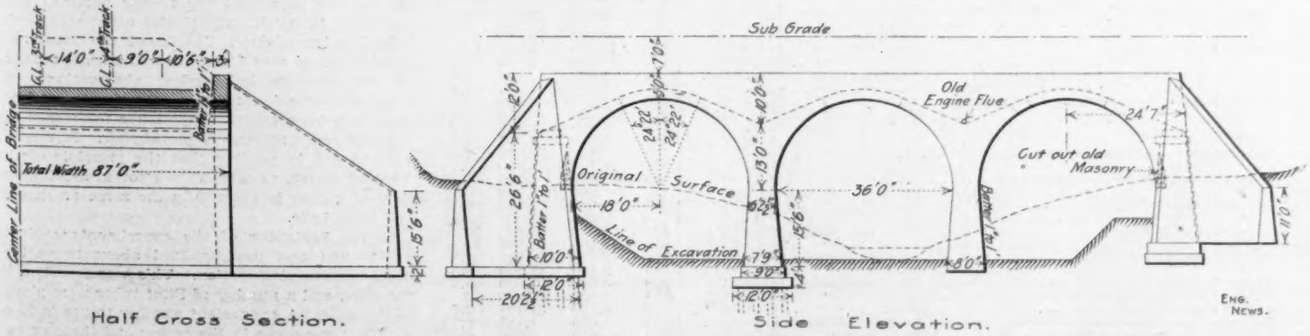


FIG. 2. FOUR-TRACK CONCRETE BRIDGE AT LINDENWOOD, MO.; ST. LOUIS & SAN FRANCISCO RY.
C. D. Purdon, M. Am. Soc. C. E., Engineer of Maintenance of Way.

of that exhausted is not necessarily fresh, unless supply pipes are fitted as well as exhaust. The principal practical objection to a supply system of ventilation is that in cold weather it is very difficult to avoid unpleasant draughts from it, and it is apt to be shut off. In the tropics, however, where ventilation is most needed, the cooling currents from a supply system are found grateful and pleasant.

At present, using electric power, a great many more fans are fitted than was customary when steam was used. There are advantages in using a number of separate fans. The piping is simpler and fewer holes in watertight decks and bulkheads are required. But with steam power the use of a number of small fans would involve a network of steam and exhaust pipes which could not be considered for a moment.

Table I. shows the number, size and rated power of the electric fans used for ventilating the battleship "Missouri." Later battleships, now building, have very similar plants. On the "Missouri" the total rated horse power of ventilating fan motors reaches the respectable total of 87, and many of these motors run nearly twenty-four hours a day for weeks at a time. The motors are required to show the highest efficiency commercially obtainable, but until experiments which have now been in progress some two years at the Model Basin were undertaken, very little was known of the actual efficiencies of the fans on the market. The Bureau of Construction and Repair concluded to investigate this question, and the work has been carried on at the Experimental Model Basin as opportunity permitted, under the direction of the writer.

The solution of the problem of supplying a compartment or number of compartments on a ship with fresh air requires the solution of two interdependent problems, which may be stated as below:

(1) Given a properly designed system of piping and outlets, with what maintained pressure at the fan outlet will this system deliver the required quantity of air?

(2) What fan will deliver at its outlet the required quantity of air and maintain the required pressure with the minimum expenditure of power?

The experiments made have dealt mainly with the second problem. It was determined in the beginning to obtain results from the fans when working under conditions practically the same as when in service on board ship. This required that each fan should discharge against pressure into a pipe somewhere near the size of its outlet and that the pressure in the pipe and velocity of the air should be determined simultaneously with the actual power being delivered to the fan.

A fan with its motor removed and its inlet free was connected to a discharge pipe of appropriate size and driven through an accurate spring torsion dynamometer by electric motors of wide speed variations and delicate speed control. Two motors with Ward-Leonard control were found to cover satisfactorily the fan sizes tested, ranging from fans absorbing about 10 HP. at 500 revolutions per minute to little fans taking less than 1 HP. at more than 2,000 revolutions per minute.

The dynamometer being used to determine the gross work or work delivered to the fan, it was necessary to ascertain the net or effective work—its ratio to the gross work being the efficiency of the fan. Now the effective work done in delivering a quantity of air to a pipe at a given velocity and pressure is made up of three components:

(a) The work done in forcing the volume of air into the pipe against pressure.

(b) The kinetic energy of the air, due to the velocity with which it passes into the pipe.

(c) The work done upon the air in compressing it from the atmospheric pressure at which it approaches the fan to the pressure at which it passes into the pipe.

The latter component is too small to be considered in ordinary ventilation work. For a pressure of 21 lbs. per sq. ft, or 2 1-3 oz. per sq. in., this work of compression is only 1-3 of 1% of the work of discharge against pressure alone. But this pressure is far above the pressures used in ventilation work, for which the work of compression is clearly negligible compared with the sum of the work of discharge against pressure and the kinetic energy.

For ventilation work and particularly for testing ventilation fans, it is more convenient to measure air pressures in pounds per square foot than in inches of water or ounces per square inch.

For the purpose of determining velocity and pressure in the discharge pipe of a fan, Pitot tubes were used, connected with floating manometers. The manometers were so arranged that [illegible] were zero reading, that is, weights were applied which counterbalanced the pressure inside the floating manometer so that this pressure was weighed, as it were, the manometer, although free to move vertically, being always brought back to one position.

Fig. 1 shows the type of Pitot tube finally developed and used in these experiments. It is [illegible] that it consists of a double tube. The common axis is placed parallel to the center line of the pipe. The outer tube has longitudinal slots in it through which the pressure in the flowing current of air reaches the annular space between the inner and outer tubes. The impact side of the tube is connected to a manometer and the pressure side to a different manometer. Generally a number of Pitot tubes were used across a given section of pipe. The manometers used had a number of compartments, each tube being connected to one compartment, thus the results were averaged mechanically by the manometers. Experiment shows that the results thus obtained were probably more accurate than when using separate tubes and plotting the curves of discharge upon diameter of pipe, etc.

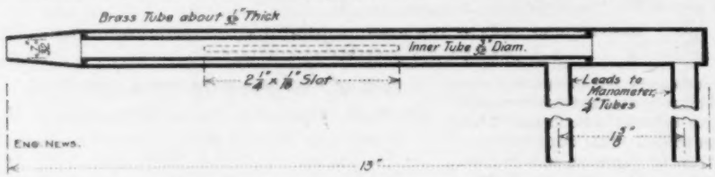


FIG. 1. PITOT TUBE FOR DETERMINING VELOCITIES OF AIR CURRENTS IN VENTILATING PIPES.

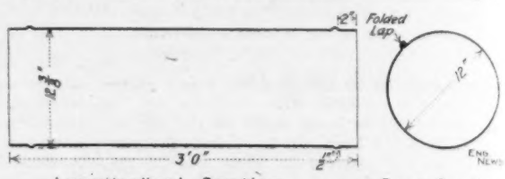


FIG. 5. SECTION OF PIPE USED IN MEASURING FRICTION OF AIR.

The Pitot tube has been more or less discredited in the past as an appliance for measuring the velocity of fluids, many having maintained that the theoretical formula is inaccurate. As a matter of fact, the difficulty has been with the type of tube. As regards the impact portion of the tube, there is no difficulty. Experiments, notably those by Mr. W. M. White, described in a paper read before the Louisiana Engineering Society in May, 1901, entitled "The Pitot Tube—Its Formula," demonstrated conclusively that for water, considering the impact side of the tube only, the theoretical formula is practically exact. As regards the pressure side, it is necessary to communicate the pressure in the moving current of air to the air at rest within the tube. This obviously can be best done by having a tube of such shape and proportions as to disturb as little as possible the natural pressure in the moving current, and to maintain as long as possible contact between the moving current and the air at rest within the tube. Pitot tubes in which the pressure openings consist of small round holes must be necessarily inaccurate, as the aspiration effect of a current moving across such an opening is large and irregular. Experiments in currents of air with such Pitot tubes as are shown in Fig. 1 show no aspiration effect. Prof. A. F. Zahm, of the Catholic University in Washington, has experimented in air with tubes of the type devised by me and compared the results obtained from the Pitot tube with practically exact results obtained independently. He found the Pitot tube results agreed very closely indeed with the results of the accurate independent observations, and there seems no doubt that a properly shaped Pitot tube is a very accurate appliance for measuring velocity and pressure of moving air. It may be pointed out in passing that the principle of the Venturi meter, so well known for measuring the flow of water, is essentially the same as that of the Pitot tube.

In the beginning of the experiments a single Pitot tube was used, shifted about to various points in the pipe section. This was found to be too slow, and a number of Pitot tubes were placed in the pipe. A convenient number to use is 13 or 9. That gives one in the center and three or two in each quadrant of a rectangular pipe. In a circular pipe the number makes no difference, and the majority of tests were made with 10 tubes so scattered over the section that each tube was

TABLE I.—Sizes, Capacities, etc., of Fixed Ventilating Fans on U. S. S. "Missouri."

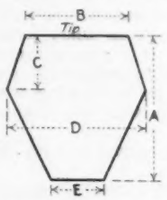
Ship's number of fan.	Nature of work to be done by fan.	Makers' designation of fan.	Size of outlet, inches.	Designed revolutions per minute.	Designed delivery, cu. feet per minute.	Gross volume ventilated by fan, cubic feet.	Designed HP. of motor for designed delivery of fan.
1	Supply to quarters and store rooms—forward	70-in. steel plate	24⅜ x 22½	577	10,300	73,328	8
2	Supply to forward magazines	45-in. " "	15⅝ x 13⅛	900	3,760	23,303	3
3	" " "	45-in. " "	15⅝ x 13⅛	900	3,760	23,303	3
4	Supply to dynamo rooms	70-in. " "	24⅜ x 21⅛	577	10,300	5,944	8
5	" " "	70-in. " "	24⅜ x 21⅛	577	10,300	5,944	8
6	Exhaust from hoods over dynamo engines	No. 5 cast shell	11-in. diam.	1,275	1,210	.....	1.5
7	" " " "	No. 5 " "	11-in. "	1,275	1,210	.....	1.5
8	Supply to passages and wash rooms amidships	No. 5 " "	11-in. "	1,275	1,210	8,390	1.5
9	" " " " "	No. 5 " "	11-in. "	1,275	1,210	8,856	1.5
10	" " " " "	No. 5 " "	11-in. "	1,275	1,210	9,745	1.5
11	" " " " "	No. 5 " "	11-in. "	1,275	1,210	9,361	1.5
12	Exhaust from passages and wash rooms amidships	No. 6 " "	14-in. "	1,150	2,150	15,260	2.5
13	" " " " "	No. 6 " "	14-in. "	1,150	2,150	15,260	2.5
14	Supply to berth deck with casemate aft	No. 3 " "	8-in. "	1,750	695	7,263	0.75
15	" " " " "	No. 3 " "	8-in. "	1,750	695	7,263	0.75
16	Supply to evaporator room	No. 3 " "	8-in. "	1,750	695	1,820	0.75
17	" " "	No. 3 " "	8-in. "	1,750	695	1,820	0.75
18	Supply to engine room	80-in. steel plate	28⅜ x 23½	506	13,200	22,845	10
19	" " "	80-in. " "	28⅜ x 23½	506	13,200	22,845	10
20	Supply to magazines—aft	No. 6 cast shell	14-in. diam.	1,150	2,150	18,209	2.5
21	" "	No. 6 " "	14-in. "	1,150	2,150	18,209	2.5
22	Supply to steering engine rooms and store rooms	No. 5 steel plate	14⅝ x 14	808	4,520	27,000	3.5
23	Exhaust from steering engine room	60-in. " "	22 x 17⅛	675	6,520	29,000	5
24	Supply to quarters aft	50-in. " "	14⅝ x 14	808	4,520	32,127	3.5
25	Exhaust from officers' water closets	No. 3 cast shell	8-in. diam.	1,750	695	1,152	0.75
26	Exhaust from crew's water closets	No. 3 " "	8-in. "	1,750	695	4,600	0.75
27	Supply to ready service magazines	No. 0 " "	5-in. "	2,200	195	450	0.25
28	" " " "	No. 0 " "	5-in. "	2,200	195	450	0.25
29	" " " "	No. 0 " "	5-in. "	2,200	195	1,200	0.25
30	" " " "	No. 0 " "	5-in. "	2,200	195	1,200	0.25
31	" " " "	No. 0 " "	5-in. "	2,200	195	675	0.25
32	" " " "	No. 0 " "	5-in. "	2,200	195	675	0.25

ing ring containing one-tenth the area of the pipe.

The Pitot tubes were made up permanently into a section of pipe which was inserted in the line as close as possible to the fan. It was found that it could be readily placed within eight or nine diameters of the pipe from the fan outlet without the turbulence of the air appreciably affecting the results. The results of observations were corrected for the friction head necessary to overcome the length of pipe between the fan outlet and the Pitot tubes, the object being to obtain results corresponding as nearly as might be to the fan outlet.

Since trials must be made under various conditions of temperature and air pressure, the variations in which must necessarily effect the results, it is obviously desirable to reduce all results to standard conditions. These standard conditions were assumed to be with air at a Fahrenheit temperature of 70°, a barometer height of 30 ins., a humidity of 70%, corresponding to a wet bulb temperature of 63.5° F. Under these conditions a cubic foot of air weighs .07465 lb. It was further assumed that the volume of air delivered did not vary with the density if the revolutions were unchanged, but that the power absorbed varied directly as the density and the resulting pressure directly as the density, the efficiency remaining unchanged. These assumptions can not be much in error, and, the corrections to reduce to standard conditions being small in any case, the standard condition results are substantially as accurate as the original experimental results.

In testing a fan it was run at a number of different revolutions, and at each speed of revolution the pressure in the pipe was varied so that the fan was tested throughout the whole range of conditions which it might ever encounter in practice. The final results after all calculations are plotted into characteristic curves. Typical characteristic curves are shown in Figs. 2, 3, and 4. It is seen that contour curves of efficiency, horse power absorbed and pressure in discharge pipe are plotted upon the prime variables of revolutions per minute and cubic feet of air delivered per minute. These characteristic curves show just what amount of air a fan will deliver at a given number of revolutions against a given pressure, also the power it will absorb in doing this and its efficiency. Thus they supply complete information as to the working of the fan under any possible conditions. The comparative data of the fans whose characteristic curves are given in Figs. 2, 3 and 4 are given below.



Comparative Dimensions of Three Cast Shell Fans.

Curves of	A	B	C	D	E	Diam. Impell'r.	Diam. Outlet.	Diam. Inlet.	No. of Blades.
Fig. 2	5¼ in.	4⅝ in.	4½ in.	5⅞ in.	2 in.	21 in.	11¾ in.	11¾ in.	6
Fig. 3	7 in.	6 in.	5⅞ in.	7¼ in.	1½ in.	22 in.	11 in.	10 in.	8
Fig. 4	7 in.	5 in.	4 in.	7½ in.	3 in.	20 in.	10½ in.	10½ in.	6

These fans are of three different makes, but do not differ much in type. It is seen that their characteristic curves are essentially similar in general features, but the maximum efficiencies shown are very different. There is no obvious reason for the wide variation of efficiency, but compared with centrifugal pumps, for which an efficiency of 80 per cent. is claimed, it is evident that the efficiency of all these fans is very low. Some 40 characteristic curves of fans have been determined by the experiments at the Model Basin, and it is found that very few fans indeed reach a maximum efficiency as great at 60 per cent. Since in ordinary working a fan can not be expected to be under the conditions corresponding to the very maximum efficiency, it is safe to say, speaking generally, that ventilation fans in practice are working at an efficiency probably ranging from 50% to 33 1-3%. This condition of affairs can not be regarded as satisfactory, and there is great need for a fan which will show an efficiency of 70% or more when discharging against a pressure of about 5 lbs. to the square foot, or 1 in. of water.

There are several formulae of interest in connection with the working of fans. The well-known law of similitude connecting the working of similar fans of varying dimensions gives the relation between revolutions, power, etc., when proceeding from a small fan to a large fan exactly similar. For instance, if we have a fan which is n times as large as a small fan, then the following formulae apply, capital letters referring to the large fan, small letters to the small fan:

$$R = \frac{r}{\sqrt{n}}, \text{ Revolutions per minute,}$$

$T = n^4 t$, Torque,
$I = in^{3.5}$, Power.
$L = ln^{2.5}$, Delivery,

$V = v\sqrt{n}$, Velocity,
$P = pn$, Pressure.

What we wish principally to know is the delivery of a given fan against a known pressure. This can be expressed by the following formula:

$$L^2 = C_1 \frac{D^4 W^2}{1000000} \left(R^2 - C_2 \frac{22630000}{D^2} p \right)$$

Where L denotes delivery of the fan in cubic feet per minute, D denotes diameter of the fan impeller in inches, W denotes width of the blade tips in inches, R denotes revolutions per minute of the fan, and p denotes pressure against which the fan is working in pounds per square foot. C_1 and C_2 are coefficients which vary from fan to fan. C_2, or the pressure coefficient, varies but little for 6 or 8-bladed fans with little or no curve to the blade, of ordinary commercial type. Its value for such fans ranges from about 1.6 to about 1.85, a fair average value being not far from 1.7. C_1, or the delivery coefficient, varies somewhat radically from fan to fan, and is difficult to reduce to formula. Analysis of a number of characteristic curves showed that the region of maximum efficiency was found at deliveries for which the radial air velocity at the tips of the blades varied from 5½% to 8½% of the circumferential velocity of the blade tips.

Although characteristic curves of delivery, etc., are all we need know about the fans, for their proper application, we need to know for a given case the pressure in the pipe required to maintain

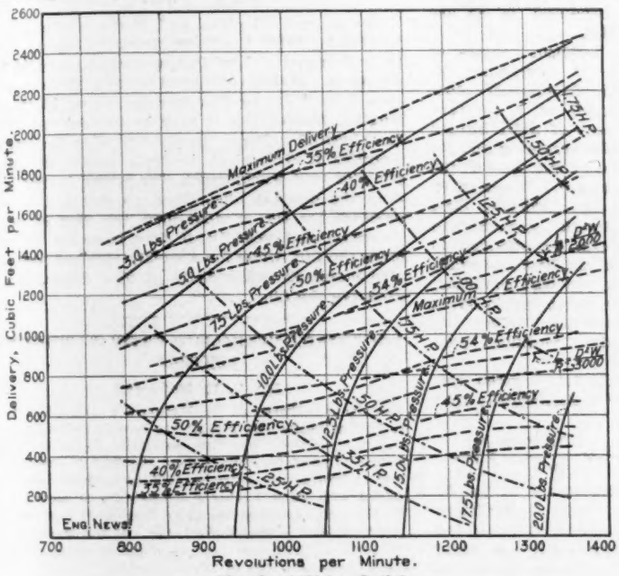


Fig. 2. 11¾-in. Outlet.

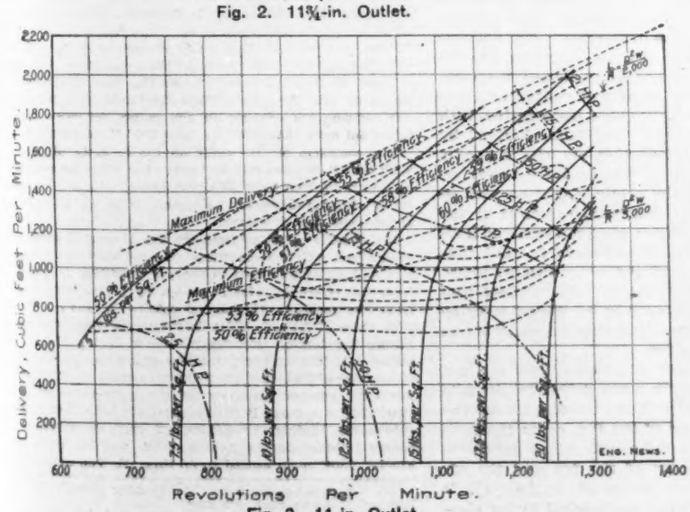


Fig. 3. 11-in. Outlet.

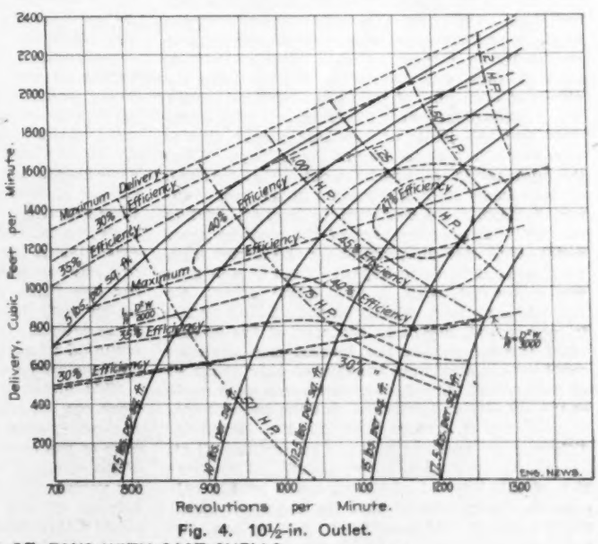


Fig. 4. 10½-in. Outlet.

FIGS. 2, 3, 4. CHARACTERISTIC CURVES OF FANS WITH CAST SHELLS.

the required discharge. Some preliminary experiments have been made in this connection in order to test the friction of air in plain cylindrical pipes. Since air varies greatly in density with the variations of the barometer and thermometer, it appears advisable to express its frictional coefficient by a quantity which changes but little, if any, with changes of variation of density. So

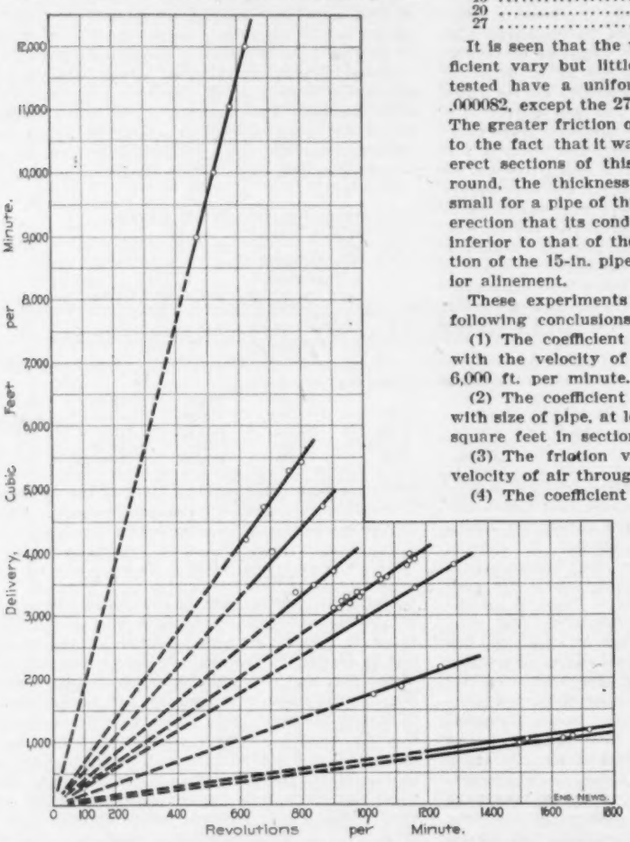


FIG. 6. RELATION BETWEEN REVOLUTIONS OF FAN AND DELIVERY OF PIPES ON VENTILATION SYSTEM OF BATTLESHIP "MISSOURI."

let fw denote the frictional resistance in pounds of one square foot of surface to air moving over the surface with a velocity of one foot per second, where f is the frictional coefficient of the air and w the weight in pounds of a cubic foot of it. Careful experiments were made to determine this coefficient and the laws governing its variation in pipes of 6, 9, 12, 15, 20 and 27 inches in diameter, of circular section, constructed as indicated in Fig. 5, of galvanized steel No. 22, U. S. standard gage. The pipes were not soldered or riveted in place, as they had to be put up and taken down repeatedly in connection with tests of various sizes of fans, but before the friction tests the pieces of each size of pipe were carefully trued. When erected they were alined as straight as possible and the joints at the laps wound outside with adhesive tape to prevent air leakage. While the pipes tested were perhaps not quite as smooth as permanent pipes constructed in the best manner, I think their condition as regards friction was fully as good as that of the average sheet metal ventilation pipe, except for the largest pipe, which was difficult to adjust. Each size of pipe was connected with a fan which forced air through it up to a velocity in the vicinity of 100 ft. per second, except in the case of the largest pipe, through which the largest fan available could give a maximum velocity of only about 80 ft. per second. Careful measurements were made of the velocity and pressure near the fan and also at a point 73 ft. further down the pipe. From the difference in pressure at the two sections 73 ft. apart, the pressure head equivalent to the friction of this interval of the pipe was readily calculated. It was found that for the pipes tested the friction varied practically exactly as the square of the speed. The frictional coefficient f, as already defined, was practically constant in each case through the range of speed experimented with, and the values for the different size of pipe were as below:

Diameter of pipe, ins.	Value of f.
6	.0000813
9	.0000820
12	.0000833
15	.0000750
20	.0000800
27	.0001030

It is seen that the values of the frictional coefficient vary but little with size of pipe. Sizes tested have a uniform coefficient of practically .000082, except the 27-in. pipe and the 15-in. pipe. The greater friction of the former is probably due to the fact that it was found almost impossible to erect sections of this pipe smooth, straight and round, the thickness of the metal being rather small for a pipe of this size. It was obvious after erection that its condition as regards friction was inferior to that of the other pipes. The low friction of the 15-in. pipe was probably due to superior alinement.

These experiments appear consistent with the following conclusions:

(1) The coefficient of friction does not change with the velocity of the air for velocities up to 6,000 ft. per minute.

(2) The coefficient of friction does not change with size of pipe, at least up to sizes three or four square feet in sectional area.

(3) The friction varies as the square of the velocity of air through the pipe.

(4) The coefficient of friction for pipes of the best workmanship in the best condition is as low as .00008.

The published tables of the B. F. Sturtevant Co. on the friction in pipes correspond to a constant coefficient of .0001 instead of .00008, assuming that for the Sturtevant tables the air weighs .075 lb. per cu. ft. While the coefficient .0001 is 25 per cent. greater than what can be obtained in pipes of the best workmanship in the best condition, it does not appear to be an unreasonable value to use for working purposes.

If we take a fan discharging into a given system of piping, it can be shown theoretically that if the formula

$$L^3 = C_1 \frac{D^4 W^3}{1000000} \left(R^3 - C_2 \frac{22630000}{D^3} p \right).$$

is correct, and all pipe resistances vary as the square of velocity of the air, then the discharge through the system is directly proportional to the revolutions of the fan. In practice it was found by experiments with the ventilating system of the "Missouri" that the discharge was proportional to the revolutions of the fan. Fig. 6 shows on one diagram curves of fan revolutions and delivery in cubic feet per minute plotted from observations on a number of the ventilation systems of the "Missouri." These were tested with all outlets wide open and the spots obtained by experiments are all indicated on the diagram. Curves of delivery and revolutions are shown as lines radiating from the origin, the solid part of each line extending over the range covered by the experiments. It is evident that the straight lines properly represent the observed facts, and that for the "Missouri" systems experimented with, which were large and small, some supply and some exhaust, the quantity of air moved may be regarded in each case as directly proportional to the revolutions of the fan.

This being the case, it follows that the net work put into the air by a fan delivering air into a given system of piping, varies directly as the cube of the revolutions of the fan, or as the cube of the quantity of air delivered. If, as air delivery varied, the efficiency of the fan and the efficiency of the motor remained unchanged, it would follow that the power absorbed by an electric motor in driving a fan attached to a given system of piping would vary as the cube of the revolutions of the motor. Since in practice both efficiency of fan and motor vary with the delivery, the above relation will not hold for wide variations of delivery, but for moderate variations we may expect to find the total electrical power required varying very approximately as the cube of the revolutions of the fan, or the cube of the air delivery. Owing to the nature of the fan efficiency curves the variation of fan efficiency with revolutions is not likely to be great for practicable changes of revolutions, so it seems safe to assume in dealing with such problems that the power delivered to the fan from the motor in moving air through a given system of pipes varies throughout a fairly wide range directly as the cube of the revolutions of the fan or as the cube of the quantity of air moved.

It is of interest in this connection to note the nature of pipes for constant pressure. If we have a pipe main with no outlets and wish to have the pressure quite the same at each end, it is necessary to increase the area of the pipe in the direction of the flow of the air in order, by checking the velocity of flow, to make up for the loss of pressure due to friction. In the case of round or square pipes, if do denote the diameter of pipe at the fan, d its diameter at a distance x from the fan, d and x being measured in feet, while g denotes acceleration due to gravity and f is the coefficient of friction of pipe, we have for a supply pipe of constant pressure

$$d = do + 2\,g\,f\,x,$$

and for an exhaust pipe,

$$d = do - 2\,g\,f\,x.$$

These are conical pipes, and, if the coefficient of friction is .00008, the taper necessary corresponds to an increase of 1 in. in diameter to every 16 ft. of length. If the coefficient f is .0001, the increase should be 1 in. in diameter for every 13 ft. of length. Incidentally it may be pointed out that for pipes of uniform pressure passing the same quantity of air, and of the same length, the supply pipe will waste much less power in friction than the exhaust pipe, since, to obtain uniform pressure for the exhaust pipe, the area of pipe decreases and velocity of flow increases as we leave the fan, while for a supply pipe the area of pipe increases and velocity of flow decreases as we leave the fan.

A NEW SYSTEM OF CHANGING WATER IN LOCOMOTIVE BOILERS.*

By A. R. Raymer.†

At the roundhouse of the Pittsburg & Lake Erie Ry. at McKees Rocks, Pa., a plant has been in successful operation since November, 1903, by which the foul water is removed from locomotive boilers, the heat is saved and used in heating the water for refilling, and the boiler is refilled with water having a temperature of about 320° F.; the whole operation requiring from 20 to 35 minutes, depending on the size of the boiler. If the condition of the boiler at the commencement of the operation showed steam pressure of 100 to 125 lbs. per sq. in., and if the fire were "banked," which is desirable, the steam pressure during the process will not have fallen below about 75 lbs. per sq. in. This water change is made without allowing any steam to escape in the atmosphere, and also without discharging any water on the floor of the round house or into the pits. While this work is being done the temperature changes in the boiler are very slight, being not more than 30° (say from 350° F. to 320° F.).

The condition of the water on the P. & L. E. Ry. is such that it is necessary to remove the plugs for washing only once in from 20 to 45 days; during this time the water is changed whenever necessary, or on an average of about once each five days.

The benefits resulting from the use of treated water, in comparison with the conditions existing when the locomotive feed water was used in the raw condition as pumped from the rivers are clearly shown by a few facts taken from the records. Comparing results in August, 1902, with those of August, 1904: Raw water having been used during the former, and treated water during the latter period. A. The number of trains given up on the road on account of leaking boilers during August, 1902, was 27 while the number given up for the same cause in August, 1904, was two. B. The number of trains that had to reduce the loading, by setting off cars, on account of boilers leaking, during August, 1902, was 13, while for August, 1904, none needed to do this. C. The number of

*From a paper presented at the October meeting of the Western Railway Club, Chicago.

†Assistant Chief Engineer, Pittsburg & Lake Erie Ry., Pittsburg, Pa.

through trains, during August, 1902, with delays of one hour or more, that had locomotives changed at McKees Rocks, on account of boilers leaking, was 31; while the corresponding number for August, 1904, was only three. By use of the plant here described, locomotives requiring a change of water, have their fires cleaned in usual way and are sent to roundhouse preferably with fires banked and steam pressure at about 100 to 125 lbs. Blow off cocks have been placed in the left side of the firebox near the bottom. An overhead 2½-in. blow-off pipe is located between engine pits, with a pipe coupling located about 6½ ft. above the floor opposite the blow-off cock in boiler, when the locomotive is in proper condition in roundhouse. The other end of the blow-off pipe connects with a manifold on the wall of roundhouse. A flexible pipe with necessary joints, gage, drip cock, and extension pipes for reaching blow-off cocks, when located in front of boilers, is mounted on a light truck for convenience of operation. This truck is placed in position opposite the blow-off cock, and connected therewith, and also with the blow-off pipe overhead, after which the valves are opened and the water in the boiler is forced out by the steam pressure in 10 to 20 minutes. When water is all blown from boiler the blow-off valve in the manifold is closed and the "superheated" water (at temperature of 300° F. and with pressure of 125 lbs.), valve is opened in same manifold and the boiler is quickly refilled with this pure water forced into the boiler through the blow-off cock, after which the valves are closed and the flexible pipe truck is disconnected and removed. During this process there remained in the boiler a steam pressure of about 75 lbs. after foul water was fully removed; the pure water is forced in against this pressure.

It has been found desirable to have the manifolds include the following service pipes: 1, Live steam, at about 150 lbs.; 2, blow-off pipe; 3, superheated water, at a temperature of about 300° F. and with pressure of about 125 lbs.; 4, hot water, at a temperature of about 200° F., that is the hot well temperature, and with a pressure of about 125 lbs.; 5, cold water, at supply temperature, say about 50° F., and at about 90 lbs. pressure; 6, test water, at supply temperature and at any desired pressure up to 300 lbs.

Live steam is used for heating empty cold boilers, which can be safely done, in about 10 minutes' time, in which time the temperature is changed from cold conditions up to about 300° F. The action of the steam on the empty boiler shell is uniform throughout its mass; it consequently causes no unequal expansion, and therefore no bad results. Live steam is also used for increasing the temperature and pressure in a boiler full of water and under low steam pressure.

The blow-off pipe from the manifold is used to convey blown off water and steam to the blow-off tank—described later.

The superheated water is used for refilling boilers when water is changed for filling empty boilers after they have been "warmed up" by use of live steam.

Hot water is used for filling boilers "whistle full" when hydrostatic test is to be applied by "test water" at proper pressure; hot water is also used to cool down boiler shells quickly and safely. Say a boiler has 100 lbs. steam and it is desired to have it empty and cool as quickly as possible, the water is blown out of the boiler and the steam is allowed to follow until the pressure is not more than 10 to 15 lbs. (The temperature of the metal will still be up to about 300°.) The valves are then changed and "hot water" is forced in, which cools the shell gradually, after which cold water can be mixed with the hot water for further cooling. Cold water is used for removing mud, scale, etc., when necessary, by old way of washing. Test water is used as described above for making hydrostatic pressure in boiler; this is furnished by a pump set to the pressure wanted, which pressure can be held as long as may be desired. As this test pressure is on the manifold it and the flexible piping up to blow-off cock, are tested each time test pressure is used.

The accompanying cut shows a diagrammatic view of the whole plant. The blow-off pipe B attached to blow-off cock A conveys water and steam from boilers to blow-off tank T; which tank is closed and furnished with a pipe E to convey steam to condenser F, and if in excess to the atmosphere there will, therefore, be atmospheric pressure in the blow-off tank T; consequently the superheated water and steam blown from the boilers will immediately on arrival at blow-off tank drop to a temperature of 212° and all heat above that amount will pass in form of steam through pipe E to condenser. A hot-well is located near, and below the condenser; it is kept full of pure water from the supply by means of a float valve G. This supply water for hot well flows through a coil in the blow-off tank, thereby extracting considerable heat from the foul water left therein, reducing its temperature below 212°.

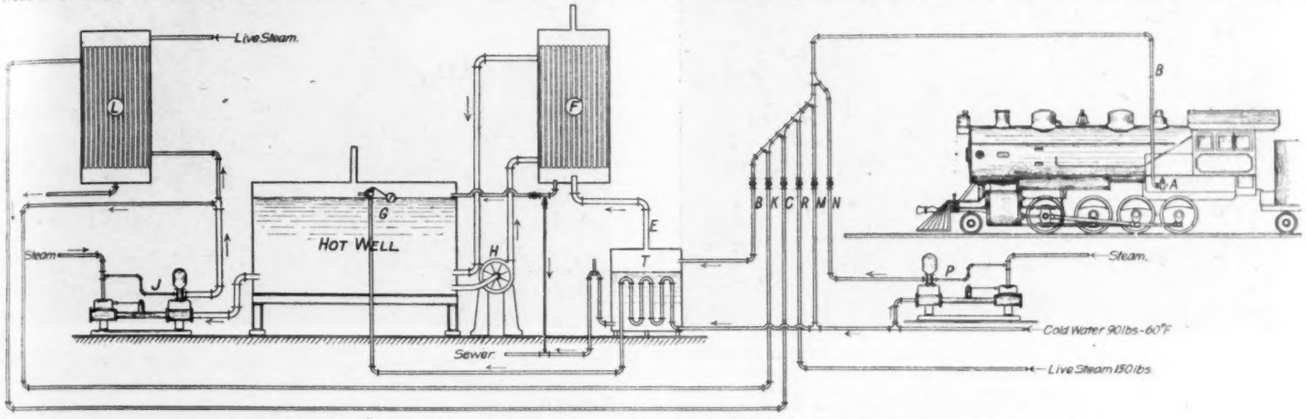


DIAGRAM OF PIPING SYSTEM FOR UTILIZING HEAT OF WATER BLOWN OFF FROM LOCOMOTIVE BOILERS, PITTSBURG & LAKE ERIE R. R.
Designed by A. R. Raymer, Assistant Chief Engineer.

A centrifugal pump H draws water from the hot well, and circulates it through the condenser F and back to the hot well, thereby condensing the steam and transferring the heat to water in the hot well. The water of condensation also flows from the condenser to the hot well, or to the sewer as may be desired. A hot water pump, J, is located below the hot well level and draws water from it and forces it by pipe K to the hot water valve in manifold, and by pipe C through a live steam heater L to the "superheated" valve in manifold. This pump is set for constant pressure of 125 lbs. and is controlled by a steam pressure regulator. The test-pump P is of the usual steam pressure regulated type easily adjusted for the pressures wanted, up to 300 lbs. per sq. in.

Few persons who have not made this work a special study will appreciate the amount of heat lost when an ordinary locomotive boiler is blown off and no attempt made to save it. An ordinary freight locomotive boiler will hold about 2,500 gals. of water when in working condition. This amount of water when at steam pressure of 100 lbs. has in it an amount of available heat above 212° F. equal to 2,600,000 B. T. U. and nearly an equal amount in the metal of the boiler shell and connected parts. The amount of heat blown off from a boiler of this kind at 100 lbs. pressure will evaporate about 2,700 lbs. of water at 212° F., and this amount of heat along with that saved from the foul water is sufficient to raise the refilling water from an initial temperature of say 60° F. up to 200° F. In delivering this refilling water to the boiler at say 300° F. the additional heat above that of the hot well, which is at about 200°, is furnished by live steam from stationary boilers.

A WEST AFRICAN SMELTING HOUSE.*

By C. V. Bellamy,† M. Inst. C. E.

In these days of advancement, when the manufacture of iron from the extraction of the ore through all the processes of preparation of smelting, refining and tempering, until it has reached the condition in which it is met with in everyday life, has been made the special study of some of the leading men of the day, whether engineers or physicists; when the great manufacturing firms of the Old and the New World vie with each other in sending their wares to all parts, and can put them on the markets at a price but a trifle above the cost of production, it is seldom that smelting works conducted after the crude manner of the ancients are met with; and it is difficult to realize that such places can still have an existence in a part of the world which is within twenty days of the great manufacturing centers of Europe.

Yet to-day there is, in the hinterland of the British colony of Lagos, West Africa, not more than three days' journey from the coast, a small village whose inhabitants have been engaged in the extraction of iron for generations past, and where the methods are the same, probably, as those practiced by the earliest workers in this metal. There is no suspicion throughout the whole of this small community of any modern improvements, and there is nothing to suggest in the character of their implements or appliances that they have been in any way influenced by suggestions from the outside world.

The people follow the habits of a life which, measured by our standard, would be termed savage, yet the existence of an industry such as herein described removes from them this stigma. They are simple and unsophisticated, but they practice an art which is unknown to the savage and which places them high above him in the social scale, while it entitles them to be considered to have reached a higher degree of civilization than many of the tribes met with in European countries where the people have been looked upon for many years past as more advanced than any of the inhabitants of the Dark Continent.

Although these smelting works are situated within one short day's march of Oyo, the capital of the Yoruba country and the seat of the Alaffin or king of that nation, it is only recently that they have been visited by a white man, for the first time, in the person of the Rev. Mr. Pinnock, the representative at Oyo of the Baptist Missions. It is to this gentleman that the writer is indebted for the information which led him to visit the place in the company of Mr. J. E. Stone, of the Public Works Department, Lagos, on Feb. 15, 1904.

The town of Oyo is situated at a distance of 35 miles to the northward of Ibadan, which is the upper terminus of the railway, and which may be reached by a journey of ten and a half hours in the train from the capital town of Lagos; the distance from Lagos to Ibadan is about 126 miles. The smelting village is therefore about three or three and a half days' journey from Lagos, which is reached by steamers from Liverpool, trading to the west coast of Africa, in about seventeen days or less.

Leaving Oyo and following an ordinary bush path in a direction almost due north, a tract of country is crossed in which there are very few habitations and where not more than two or three farms for the production of cotton, maize, yams, etc., have been established.

After a march of about 4½ hours, evidences of charcoal-burning seemed to point to the proximity of our quest, and steps had to be taken to send ahead to warn the villagers of our approach and to explain that we desired to come in peace and to go in peace; that we sought to do them no injury, but to sit down in their village and amongst them for a space. We found the people well disposed towards us and eager to offer us the hospitalities of the bush.

The community consists of about a hundred or a hundred and twenty souls, and beyond the cultivation of a few acres of provision-grounds for their daily requirements, the whole of them—men, women, and children down to the ages of five or six—are occupied in the mining, smelting, etc., of iron. They have followed this avocation, as a separate tribe, apparently for generations, though not always in this same neighborhood. The balé, or headman, explained that at one time they were located to the southward of Oyo, close to the small village of Menca, between that town and Ibadan, where there are numerous evidences of smelting works to be seen on the side of the bridle road joining the two places; but that about five years ago, say in 1898 or 1899, they migrated to their present location, where the iron ore is of better quality and easier to work.

*From a paper read at the New York Meeting of the Iron and Steel Institute.
†Director of Public Works, Lagos, Africa.

The crude ore is mined in a manner strongly suggestive of the ancient stream-workings in Devon and Cornwall, and elsewhere. In mining parlance it may be described as "placer;" the ferruginous deposit is met with at a depth of not more than from 6 to 8 feet below the surface of the ground, and occurs in a shale which is closely associated with the neighboring gneiss rock.

The shale is excavated, with the aid of a rude pick, in pieces weighing from 3 to 5 pounds, and is carried to the

FIG. 1. VIEW SHOWING PROCESS OF WASHING POUNDED IRON ORE BY WEST AFRICAN NATIVES.

(The man standing is the head smelter; the woman in the middle is standing in a well, occupied in giving the ore its first washing; the woman seated at the left is giving the ore its final washing, and at her right hand is seen a heap of washed ore.)

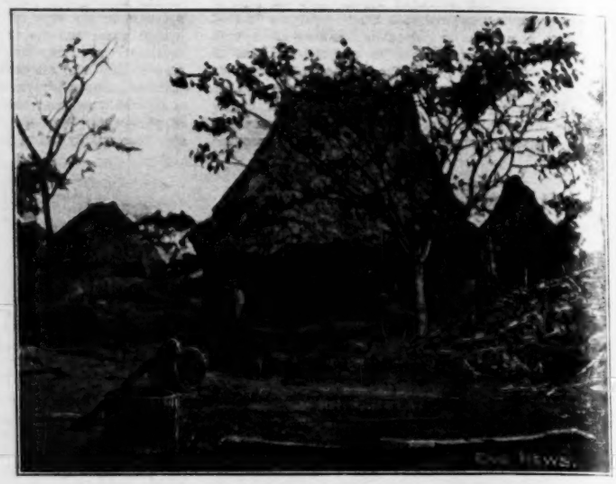


FIG. 2. VIEW OF NATIVE SMELTING HOUSE, WEST AFRICA, WITH WOODEN MORTAR AND PESTLES FOR POUNDING ORE IN THE FOREGROUND.

smelting works for treatment. This consists, firstly, in roasting it over a fire of green timber. This generally takes place at night, the small fires for the purpose being lighted up about sunset, and then left to take care of themselves until morning, when the ore is ready for further treatment. The fires are constructed of about a dozen logs of wood, perhaps 6 feet long, and 9 and 10 inches in girth, piled one above the other, and on the top are laid pieces of the crude ore in the condition in which it has come from the workings. The quantity of ore on each fire hardly exceeds a barrowful. The next morning the ore is pulverized in an ordinary wooden mortar, such as the natives use for pounding yams, etc., with the aid of a pestle of the same material, both shaped in the rudest manner. This is done by women and children, who seem to take to this work as soon as they are strong enough to wield the pounder.

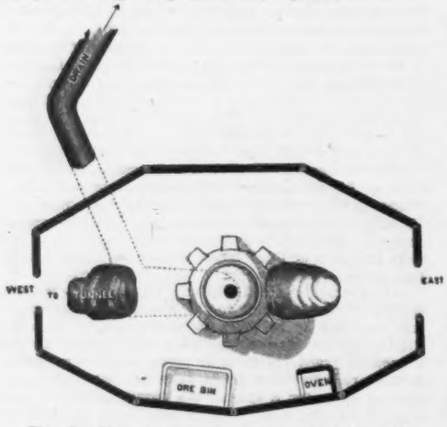


Fig. 3. Plan of Smelting House with Cupola.

The poundings are screened until there is nothing remaining in the mortar, the sieve consisting of a native-made basket, rather openly woven, and they are then borne away to the river-side for the purpose of washing or panning. This is carried out by women in the following manner: A hole is dug in the ground about 2 ft. deep, and about 2½ ft. in diameter, and is filled with water to within about a foot of the top. Into this one of the women descends, provided with a calabash tray about 18 ins. in diameter, into which she pours a quantity of ore poundings sufficient to half-fill the tray. She proceeds to wash this by means of a circular oscillating motion, which causes the contents of the tray—ore and water—to follow a circular course, by means of which the lighter, finer, and probably largely organic, matter is discarded, and falls to the bottom of the pit, while the heavier particles remain in the tray. When this has undergone washing sufficiently in the pit, it is set aside on the bank for a further and more careful washing by a second woman seated on the ground near by. This second treatment consists in placing it in another tray and sluicing it in clear water, and agitating it until the water drawn off is clear and free from coloring matter. The ore is then deemed ready for the cupola, and the residue of finer material, which is of a rich dark-red hue, and may be termed the tailings, is thrown away. The washed ore is conveyed to the smelting house and poured into the kiln, as occasion may require, in a damp state.

There are in the village altogether eleven smelting houses, and as each is an exact reproduction of the other, it will only be necessary to describe one. Each shed measures from 25 to 26 ft. in length, by about 16 ft. in width, a doorway being provided at each end. The walls are built of clay-daub, and vary in height from 4 to 6 ft.; they are not carried up to the roof, but a space is left all around for light and ventilation. At irregular intervals, around the walls, and built in the thickness of the same, rough posts are placed to carry the eaves of the roof, while the ridge is supported by two other posts planted in the interior of the hut, and steadied in each case by a rude tie-beam spanning the building from side to side at the eaves. From ground level to ridge the height is about 25 ft., so that, although the roof is covered with a thatching of palm leaves, there is little chance of its becoming ignited by the flames from the cupola. These smelting houses are, in nearly every case, placed east and west along the longer axis.

The principal feature of the interior is the cupola, which stands about the center of the shed. It is built entirely of clay in mass, and occupies a circular space, whose diameter is from 7 to 7½ ft.; the height of the cupola from floor level to the crown of the dome is about 3 ft. 9 ins. On the eastern side and facing one of the doorways is the entrance to the cupola, the sill of which is about a foot below the floor, and an irregularly-shaped depression in the floor, about 4 ft. long and 3 ft. 4 ins. wide, is provided to give access to the doorway, and therefore to the interior of the cupola. This doorway, the entrance to the furnace, occupies about a fourth part of the circumference of the cupola, and around the remaining three-fourths there are seven rough counterforts, each measuring a little less than a foot every way, alternating with six openings through the walls of the cupola, each about 18 ins. high, and tapering to 6 inches in width; the entrance to the cupola, therefore, occupies the width required for one counterfort and two openings. The sides, top and bottom of each opening slope inwards and downwards towards a point about the center of the base of the furnace.

The dome of the cupola is rounded up on the outside slightly and measures about 3 ft. 6 ins. to 3 ft. 9 ins. across, and a circular orifice or flue is left in the center of the dome about 9 ins. in diameter. A short distance below the curve of the dome a rope of twisted vines or creepers is passed round the cone and pegged down into the clay for the purpose of binding the walls securely together and preventing them from cracking and opening out, in the same manner in which an iron band or strap is applied to the cupolas of more civilized countries.

The interior of the cupola measures in its greatest diameter about 2 ft. 6 ins. at a height which corresponds to the floor level outside, and the floor or bottom of the furnace, which is rounded, is about 2 ft. below this point. The height of the furnace is about 5 ft., and the space is of an elongated egg-shape in section; the surface is rendered smooth with clay. The larger rounded end is, of course, at the bottom, and the sides taper inwards on easy curves toward the flue in the crown of the cupola.

In the center of the bottom of the cupola is a perforature about 3 or 4 ins. in diameter, which communicates with a short tunnel below the floor of the shed, to which access is had by means of a pit immediately inside the western entrance to the shed. On the northern side of this tunnel a branch is provided, passing out underneath the walls of the shed and communicating with an open drain, which is provided for the purpose of carrying off any moisture which might accumulate in the tunnel during the rainy season.

There are two other permanent features of the interior of the shed, one consisting in a small vertical oven

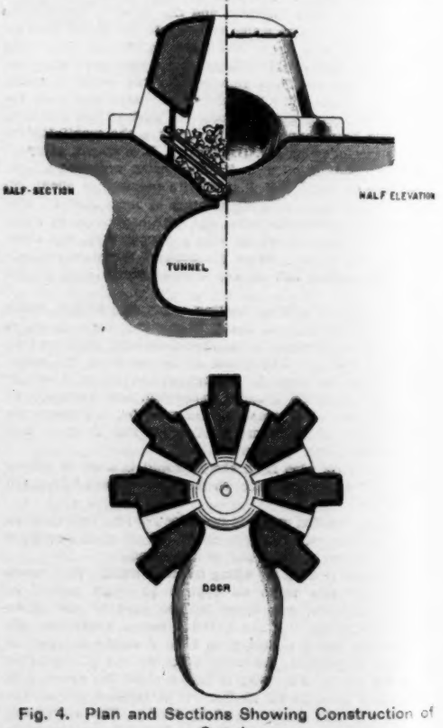


Fig. 4. Plan and Sections Showing Construction of Cupola.

about 2 ft. 6 ins. long and 1 ft. 10 ins. wide by 4 ft. in height, roofed in and enclosed on all but one of the narrow sides. This is employed for firing the earthenware pipes, each about 2 ft. long and 1½ ins. internal diameter, through which the draft is led into the

center of the fire when the cupola is working. The other fixture is merely an ore bin about 4 ft. 8 ins. long and 2 ft. 8 ins. wide, the walls of which are about 9 ins. high. In both cases these fittings are constructed of clay-daub, no stone or brick being employed for any purpose connected with the shed or its fittings, and even the tunnel is cut in through the soil and has no other support but that of its own strength, though it has to carry some share of the weight of the cupola above its inner end. Around the rest of the shed the wall-space is occupied with stacks of charcoal, calabashes of flux and metal, tools, pestles, and mortars, and a miscellaneous assortment of articles.

The process of smelting occupies a period of about 36 hours. A cupola is charged about daylight of one day, and is drawn off shortly after sunset of the following day. The first operation in preparing a cupola for smelting consists in closing the six vertical apertures. This consists in setting in each of the apertures two earthenware

Fig. 5. View Showing Earthenware Flue Pipes Drying in the Sun.

pipes, one above the other, built around with charcoal, inclining downwards towards the center of the bottom of the furnace where all the pipes concentrate; the opening is then sealed with clay to the thickness of about a couple of inches, but the entrance to the furnace is not closed until the last moment. On the following morning about daylight, or say 5.30 a. m., the actual charging of the cupola commences, firstly by closing the orifice in the bottom of the furnace which communicates with the tunnel, this being done with the aid of a cone of damp sand, roughly shaped with the hand, and forced upwards into the orifice, and caulked tightly with the same material. Live charcoal is then placed in the center of the cupola and the firing started; as soon as this is accomplished and the fire properly established, proceedings are taken for the closing of the door of the cupola. In this instance there are fixed three pairs of earthenware pipes in positions corresponding with those fixed in the six vertical apertures around the cupola. They are, as in the other cases, packed around with charcoal and finally built around with a clay seal of a thickness corresponding to that adopted in the other cases.

The result of closing up the openings and of confining the inward flow of air to the pipes is immediately apparent by a brightening of the flame and a more brisk heat. It will be seen that there are altogether nine pairs of pipes supplying the necessary draft to the fire, and although they are only rudely shaped by hand around a stick, and but partly baked, the average diameter of each pipe is about 1.40 ins. This gives a sectional area of, say 1.54 sq. ins., and as there are in all eighteen pipes supplying the indraft, and the opening in the crown of the cupola is 9 ins. in diameter, the relationship between the inflowing current of air and the escape in the dome is in the ratio of:

$$18 \times 1{:}54 :: 9 \times 9 \times .7854$$
$$= 27.72 :: 63{:}6174$$
$$= \text{say, } 3 :: 7.$$

That is to say, that the outlet is 2⅓ times as great as the inlet; by this means a description of forced draft is obtained in a very simple but effectual manner.

As soon as the fire in the cupola is well established, a condition which is quickly fulfilled as soon as the openings in the lower part are closed, a flux is thrown on to the fire through the flue in the crown of the cupola. This flux is obtained from the slag or refuse clinker from each successive smelting. How it was first obtained the headman of the village was not able to explain, but he stated that it increased as time went on, because the yield of flux from each smelting was more than sufficient for any one subsequent operation. He acknowledged that, without the aid of the flux, they would not be able to carry on their work, and that if, by any misfortune, they became deprived of all their flux, their industry would cease. He further added that when they migrated to their present location they brought with them a quantity of flux from their former workings. The discovery of this important element dates probably many centuries back, possibly to the days of the first workers in the metal, and is now, unhappily, shrouded in obscurity. It is, however, now reproduced at each operation immediately before the cupola is opened and the smelted metal drawn out. The process of its collection will be better understood when an explanation has been given of the treatment of each firing; it is perhaps the most important feature of the whole process.

It has been explained that a cupola commences to be charged at daylight, about 5.30 a. m., and about two hours afterwards, when the fire is well alight, a quantity of flux, about 5 lbs. in weight, and about 2 bushels of charcoal, are thrown on to the fire. After a further lapse of about two hours, or, say, about 9.30 a. m., this flux is drawn off through the aperture in the bottom of the hearth communicating wth the tunnel, and a similar quantity of flux as before, together with a similar quantity of charcoal, are added. This makes two charges of flux before any smelting is commenced. Again, about two hours later, or, say, 11.30 a. m., this flux, the second charge, is drawn off, after which the fire is considered to have undergone sufficient cleaning, and the real operation of smelting commences.

Firstly, about 5 lbs. of flux is applied, then about 2 bushels of charcoal, the quantities being the same as in the former charges, but immediately afterwards a quantity of iron ore of the same weight as that of the flux, say, 5 lbs., in the washed state, and still moist, is thrown into the cupola.

This operation of feeding the cupola with ore is repeated ten times from start to finish, but prior to each charge the flux is drawn off in the manner already described, and only upon the ninth and tenth, the final charging, and also immediately before the cupola is emptied, is the flux reckoned of any value for assisting in subsequent smeltings. These are, therefore, the residue of the eighth, ninth, and tenth charges. There are therefore three occasions during each firing when flux may be collected, and it may well be understood that the supply exceeds requirements. Yet upon each draw-off there is a considerable quantity of dross which is thrown to spoil, and there appears to be a certain amount of judgment required to discriminate between what is worthless dross and what is serviceable flux.

The quantity of ore put in at each charge gradually increases—using the words of the head smelter—from "the third part of a calabash," i. e. about 5 lbs. in weight, to a "full calabash and a half," or, say, about 25 to 30 lbs. of ore, which maximum is reached upon the eighth charge the last three being equal. The precise moment when the fire is ready for the reception of each successive lot of ore is a matter entirely of judgment and experience, but the interval is usually from two to three hours, a period of five hours being allowed to elapse between the last or tenth charge and the opening of the cupola. The only explanation offered in reply to my inquiries was that the fire, as seen through the flue, must be white.

At the appointed time, as as soon as the cupola gives indications of being ready to be opened, one of the attendants descends into the tunnel communicating with the bottom of the cupola, and, with the aid of an iron pricker, opens out the orifice in the bottom, thus allowing the flux to run off. The orifice is kept open and clear by means of the pricker until the flux has ceased to run. The last of this flux seems to be considered to be the best, and is without further examination set aside for use, but the first lot of the run-off, which may weigh as much as 40 lbs., is set apart for closer examination by daylight.

Then preparations are made to open the cupola, and, with the aid of a wooden crow-bar shod with iron, the clay seals over the six apertures are broken up, the earthenware pipes removed and thrown to spoil, and finally the doorway of the furnace is opened. The contents of live charcoal are raked out through the doorway with the aid of a wooden scraper, they are then drenched with water, and carried away. Then the smelted metal is revealed lying in the bottom of the furnace in a solid cake or pig. After a good deal of manoeuvring, and when nearly all the charcoal has been withdrawn, a loop of green creeper from the forest is thrust in and hooked over the cake of metal, and by this means the latter is drawn forth out of the cupola, and eventually out of the shed, in a red-hot state, and is allowed to cool off until the following morning. Subsequently it is broken up into convenient sizes and taken to the market, where it is bought up by the blacksmiths, who do the necessary puddling themselves.

Fig. 7. View Showing Method of Breaking Up the Iron Pigs by Means of a Stone Hammer and Anvil.

The quantity of ore employed from first to last in charging each cupola, taking the figures very approximately, and accepting the evidence of the head smelter, would appear to be as follows:

For the	first	charge.....	about	5 lbs.
"	second	"	"	7½ "
"	third	"	"	10 "
"	fourth	"	"	12½ "
"	fifth	"	"	15 "
"	sixth	"	"	17½ "
"	seventh	"	"	20 "
"	eighth	"	"	25 "
"	ninth	"	"	25 "
"	tenth	"	"	25 "
Total		.....		162½ lbs.

The weight of each pig of smelted metal as the yield of each operation would be, as near as one could judge, between 70 and 80 lbs. Taking the average yield at, say, 75 lbs., the ratio of metal to crude ore is as 75 : 162 = 46%. That is to say, that for every 100 lbs. of ore thrown into the cupola 46 lbs. of metal are produced. The remaining 54% of ore comes away in clinker from which the necessary flux for subsequent smeltings is selected, and the residue thrown to spoil.

Fig. 6. View Showing Two Pigs of Iron as They Have Come from the Cupola.

Probably the most remarkable feature in the whole of the process is this use of selected clinker for a flux. This may throw light upon what is now frequently a matter of doubt—namely, the medium employed by the ancients in their smelting operations.

The head smelter in the course of many conversations on the subject showed himself to be extremely intelligent and both eager and willing to supply any information sought, as well as to show and explain every operation as it took place. Amongst other things he said that to the best of his knowledge there were no smelting works in this part of West Africa, and that, indeed, he had never heard of any existing anywhere else. He said that they supplied all the markets in the neighborhood, mentioning such large centers as Oyo, Ogbomosho, Isseyin, Ibadan, and down as far south as Ijebu Ode, an extent of country covering some hundreds of square miles.

As has already been indicated, the pig iron, after it has cooled down sufficiently, is broken up into convenient lumps for the purposes of sale or barter, and beyond this undergoes no change whatever from the time it leaves the cupola to the time it reaches the smith's shop where the puddling is done. In order to witness this part of the work a visit was paid to a smithy in the town of Oyo on our return thither, and here again everything was of the most primitive character.

The bellows consisted of a pair of circular wooden bowls about a foot in diameter, connected by an air passage constructed of the same, from which two wooden pipes, to do duty for the tue-iron, lead to the hearth; over the top of each bowl is loosely secured an undressed goat-skin, to which is fastened in the center of the bowl a long bamboo rod, one of which is held in each hand. The skin is very slack, and by raising and lowering the rods alternately a more or less continuous current of air is supplied to the hearth. There is no inlet valve to these bellows, and the air supply enters by the wooden tue-pipes, a space being left between the hearth stone and the nozzles for the purpose; the bellows and hearth rest upon the ground.

The other fittings of the smithy were of a similarly primitive character. For heavier work a large smooth, undressed and water-worn stone does duty for an anvil, but for smaller work another anvil is provided like a silversmith's, made of metal produced locally. The hammers look at first sight like so many rude lumps of iron roughly handled with the same, but a closer inspection shows them to be systematically shaped and diamond-wise in section so as to expose a flat or a straight pane by a single turn of the wrist; it is of an ingenious pattern.

With such simple means as these the smith puddles the iron which is smelted after the manner already explained. To put this to the test, a piece of the rough metal as it had come from the smelting works was selected from the odds and ends in the smithy and handed over to the smith with instructions to puddle it up and shape off one end leaving the other rough and untouched. This he did without any hesitation or further preparation in the space of a few minutes, the only precaution taken being to warn the bellows man to blow gently at first and to accelerate the speed as the metal became hotter. The results were satisfactory as well as instructive, and the specimen was brought away to join the others which had been collected at the smelting house.

Getting into conversation with the smith, he explained that all the metal he used came from the smelting works which we had just visited, at Ola-igbi; there was no regular price paid for it as there is no standard of weights and measures in the country, but it is exposed for sale in little heaps; this for threepence, that for sixpence, and so on. He could not give any idea of the market value of the metal, but of this some notion had been gained at the smelting works where, as we stood to witness the pig being drawn out of the kiln, we were told that the yield was good and would fetch about ten shillings. We judged that the weight was about 60 lbs., at which rate the price would work out at 2d. per lb., or £18, 13s. 4d per ton, or perhaps six times the price of pig iron on the English market.

Among the miscellaneous articles in this native smithy there happened to be an English rosehead nail, and for curiosity's sake we asked the smith what he thought of such metal. His reply was of the most emphatic character, "It is no good!" He repudiated with striking scorn the suggestion that he might use such metal for making tools for native uses, but his reply was the same. His own native metal was good, always good, good for all kinds of tools, and he would not use English iron as it was no good for the tools that he made, hoes, axes, &c.

In the case of another smithy which we visited in a village to the southward, we found the same lumps of native iron from the same works, but here it seemed that foreign influence was beginning to be felt, and a brisk trade was being carried on in reaping and pruning hooks, knives, &c., made out of hoop iron of the ordinary type imported from Europe. But the smith acknowledged with great frankness that they were only made to sell, and with many a shake of the head said that they did not last, as the metal was not to be compared with that of native manufacture.

In the face of such strong prejudice it is hardly likely that an important, interesting, and probably now unique native industry will suffer much for some time to come at the hands of European enterprise; yet the day must inevitably arrive when the native product is run off the market by the imported and machine-made article, when the hearths of this smelting village are cold, its kilns in ruins, and its workers driven to seek other employment. It is earnestly hoped that this time is still far distant and that the peaceful, industrious community may continue for several generations to toil on in its present occupation of producing a metal which, according to the native standard, is superior to anything produced elsewhere.

Not the least important feature in this industry is the marked regularity which characterized each operation and the enthusiasm which seemed to inspire the workers. Strangely at variance with the usual custom of the Ethiopian, there was no noise, no bustle, no confusion; no sound but the hum of pre-occupation was to be heard throughout the whole village. At the right moment the kiln was prepared and lighted, sealed, charged and drawn; at the right moment, when the fire was drawn, little boys stood ready with their calabash trays to take away the live charcoal, and at the right moment they brought the necessary green creepers with which to draw the pig from the cupola, or water to quench the fire. All this indicated systematic control and the strong hand of authority, and method only acquired by long practice and passed on from one generation to the next.

Each cupola is run on the share system under a separate section of the village; there is no community of interests governing the whole village. It is a model industrial community, and may it long continue!

APPENDIX.—ANALYSES OF SPECIMENS.—By F. W. Harbord, Assoc. R. S. M., F. I. C.—It having been suggested that it would add to the value of Mr. Bellamy's paper if analyses of the ores and fluxes used and of the products obtained were given, I offered to make analyses of the samples sent from Lagos, appended. These analyses showed that the ore used is a very siliceous haematite, containing only 36.67% of metallic iron, mostly as peroxide. By roasting, the small quantity of combined water is driven off, and the little ferrous oxide present converted into ferric oxide; and by grinding and washing, the siliceous residue is reduced from 43% to 14%, and the percentage of metallic iron increased from 36.67% to 60%.

The tailings contain 56% of siliceous residue and 28% of metallic iron.

The fluxes used are ferrous silicates similar to an ordinary tap cinder, except that they are more siliceous and contain less iron. The clinker ordinarily used as a flux is the last which comes away before opening the cupola, and, is lower in silica and contains about the same percentage of iron as the clinker afterwards selected, thus confirming the experience of the workmen that this is the best flux; there is a very distinct difference between the best flux, or even the selected flux, and the clinker [illegible] to spoil, the latter being higher in silica and [illegible] iron.

The analysis of the smelted metal shows it to [illegible] iron which has been partially decarburized by the [illegible] ing flux; it is really a puddled steel, low in sulph[illegible] phosphorus; its purity in these respects account[illegible] its good qualities. The puddling carried out by the previous to forging the tool is evidently a refining to that carried out in a charcoal hearth, the metal held before the blast until sufficiently decarburized. the analyses it will be seen that the silicon wa[illegible] largely removed, and the carbon reduced from 1 [illegible] 1.0%; and it is probable that the degree of decarb[illegible] tion is varied according to the purpose for whi[illegible] tool is required.

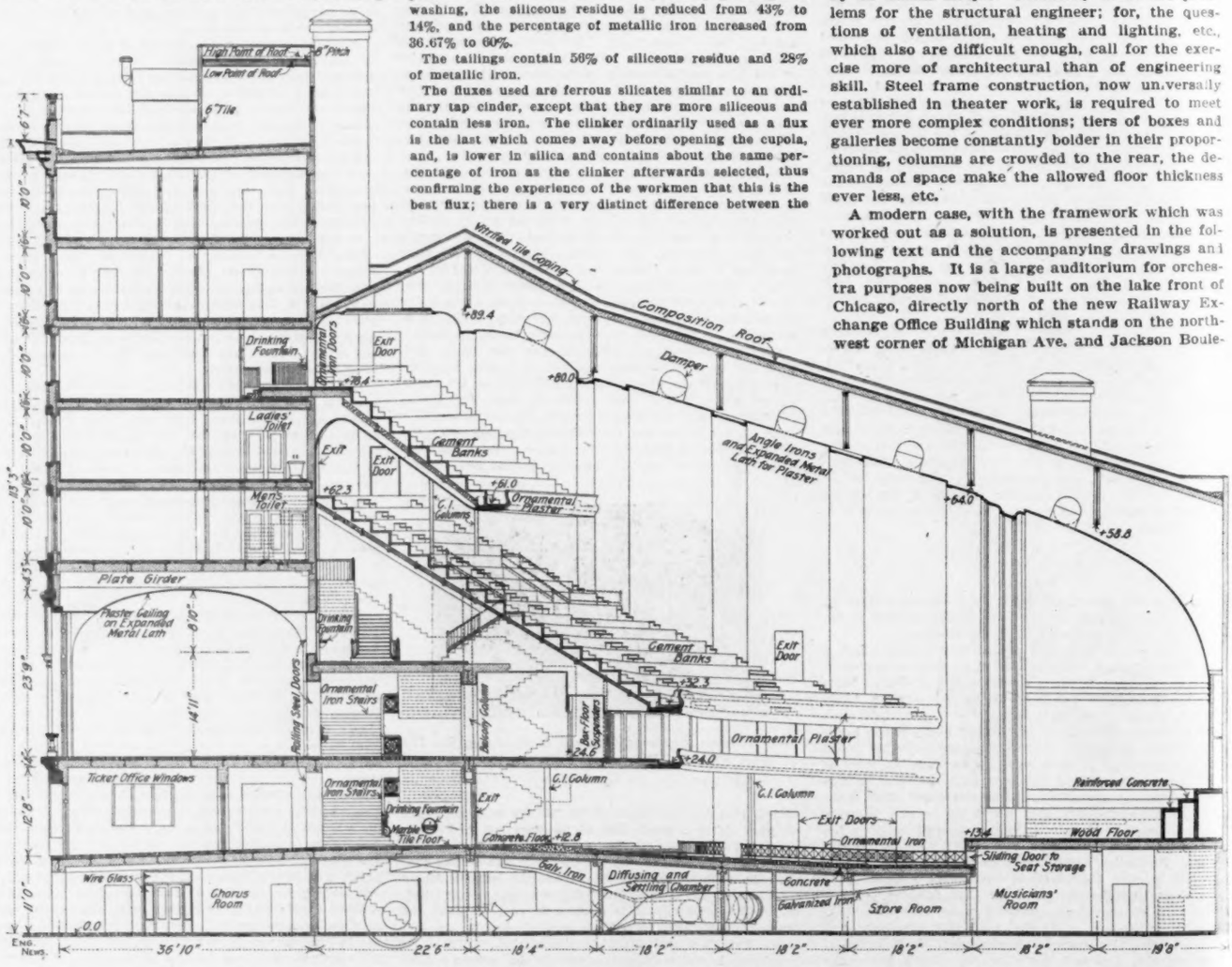
So far as the metallurgy of the process is concern[illegible] it is similar to most direct processes, the metal bei[illegible] duced by charcoal, and then partially decarburized [illegible] same furnace by means of fusible oxides, which also [illegible] ly dephosphorize the metal. It is interesting to note how complete the dephosphorization is, as the washed ore containing 0.033% of phosphorus would, if smelted in a blast furnace, give a pig iron with approximately 0.06% of phosphorus, but, under the conditions prevailing, of comparatively low temperature in the presence of oxidizing fluxes, this is reduced to 0.01%.

It is probable that the metal never collects in the fluid state on the bottom of the furnace; but as it is reduced and falls through the bath of oxidizing flux, it is partially decarburized, its melting point raised, and the temperature is just high enough to enable it to gather in the form of a metallic sponge, from which the fluid slag can be tapped off from time to time.

SPECIAL STEELWORK IN ORCHESTRA HALL, CHICAGO.

The problems which modern theater and auditorium construction places before the engineer are by no means simple. Primarily these are problems for the structural engineer; for, the questions of ventilation, heating and lighting, etc., which also are difficult enough, call for the exercise more of architectural than of engineering skill. Steel frame construction, now universally established in theater work, is required to meet ever more complex conditions; tiers of boxes and galleries become constantly bolder in their proportioning, columns are crowded to the rear, the demands of space make the allowed floor thickness ever less, etc.

A modern case, with the framework which was worked out as a solution, is presented in the following text and the accompanying drawings and photographs. It is a large auditorium for orchestra purposes now being built on the lake front of Chicago, directly north of the new Railway Exchange Office Building which stands on the northwest corner of Michigan Ave. and Jackson Boule-



Longitudinal Section on Center Line.

FIG. 1. LONGITUDINAL AND TRANSVERSE SECTIONS THROUGH ORCHESTRA HALL, MICHIGAN AVENUE, CHICAGO, ILL.
D. H. Burnham & Co., Architects; Thompson-Starrett Co., Contractors.

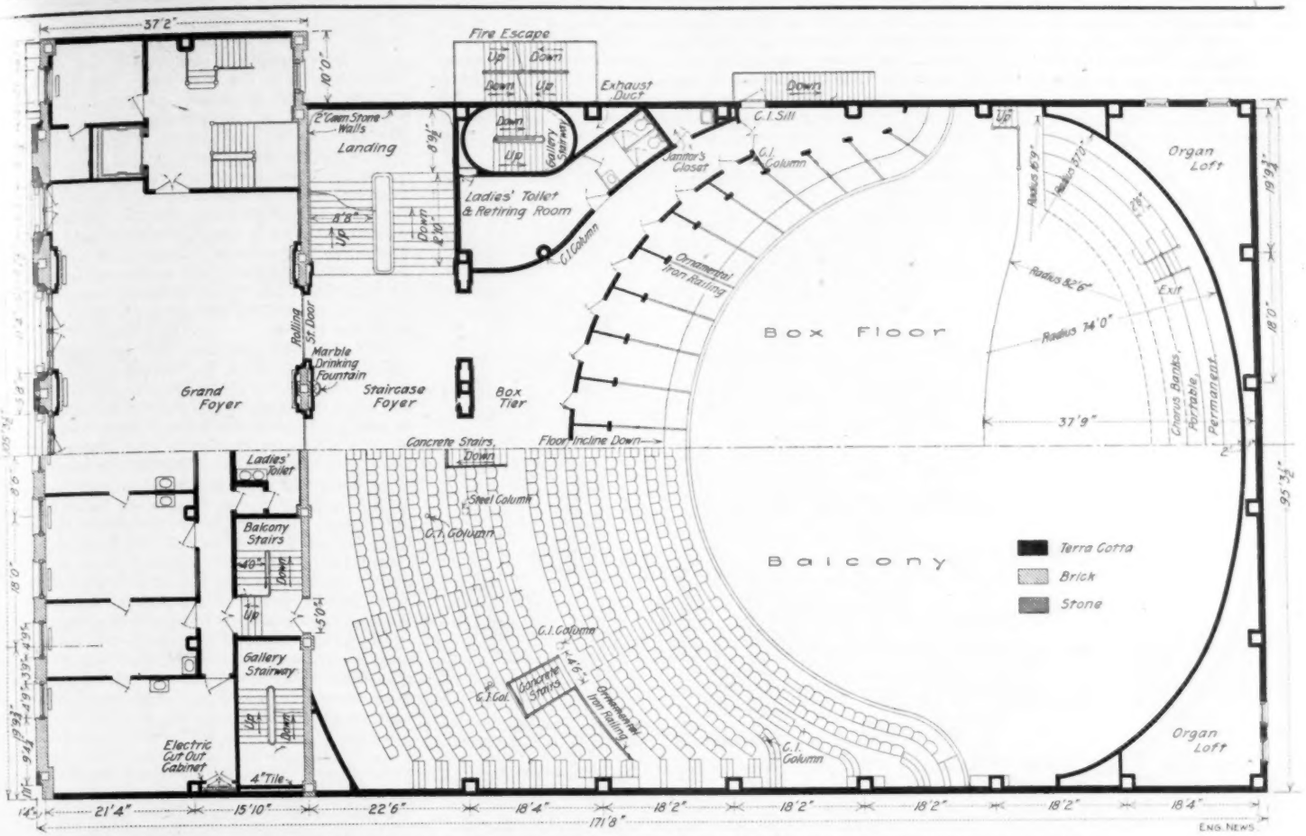


FIG. 2. ARCHITECT'S FLOOR PLANS OF BOX-FLOOR AND BALCONY, ORCHESTRA HALL, CHICAGO.

vard. "Orchestra Hall," as it is called, differs from theater structures proper in that it has no stage, but merely a platform for musicians and chorus. The rather intricate steel construction which frames the stage space of modern theaters is therefore absent here; however, stage framing rarely involves important difficulties of structural steel design.

The general arrangement of the Orchestra Hall may be understood from Figs. 1 and 2, the former of which gives a vertical longitudinal section through the building, while the latter shows half plans of the first and second overhung tiers, called respectively box tier and balcony. The "orchestra" or parterre, forms a slightly dished floor below the box tier, sloping downward toward the music platform; it is supported directly on short columns in the basement, and involves no difficulties except shop difficulties due to the fact that the floor is a doubly-curved surface. (This may be seen in the view, Fig. 11, taken Aug. 9, which shows the steelwork of this floor nearly completely erected.) There are three overhung tiers, the one above the balcony being called the gallery. Above this the auditorium space is roofed over by a sloping roof carried on large parallel chord Warren trusses extending transversely across the building. The roof itself is of terra cotta flat arches between I-beam purlins. The trusses rest on steel columns which rise through the side walls and which carry these walls as well as the roof.

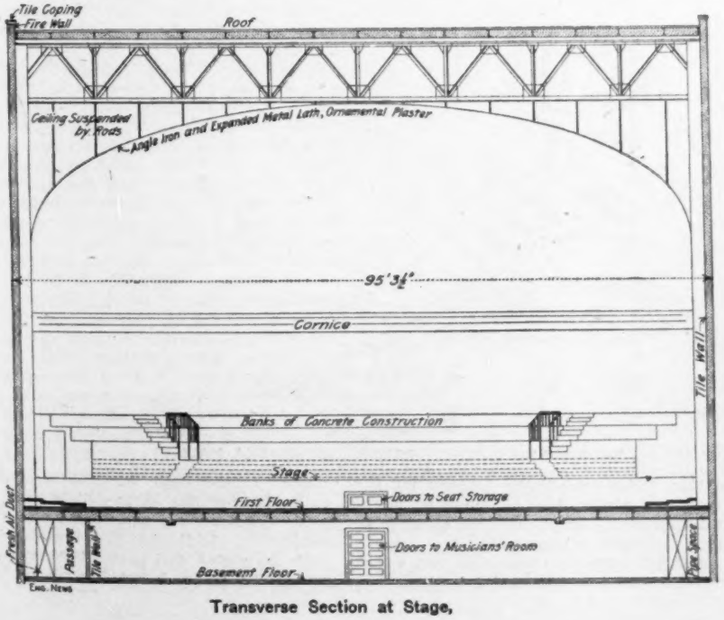
The balcony in this design is of great depth from front to rear, and has an unusually large overhang. Moreover, it is called upon to support part of the tier below—the box tier—and the greater part of the gallery load. This concentration of loading, combined with the great overhang of the balcony and the shallow floor thickness allowed, made the structural work here quite a complex problem, indeed, the central feature of the entire auditorium framing.

That portion of the building lying forward of the auditorium, that is, between auditorium and street front, is of the ordinary construction of steel tier buildings, and offers little of note. It contains the entrances to the auditorium, in its lower stories, and space for offices above.

At the south side of the building an alley or passageway 10 ft. wide is left clear, running through from street to street, except that the front portion of the building is built out over this passage in order to give an unbroken street front. Such a passageway is required by the Chicago building ordinance, which demands that theaters must front on three streets, or, if fronting on only two streets, must have a clear and unobstructed passageway 10 ft. wide along one side and opening on both streets, to serve as emergency exit. The only effect of this passage on the structure of the building is to simplify the foundation work, by removing the south wall foundation (except for two bays at the front of the building) from direct contiguity to the foundations of the tall Railway Exchange Building, which adjoins to the south.

FOUNDATIONS.—The foundation work for Orchestra Hall was, in general, very simple. The loads being relatively small, and the depth of the building below ground not great, it was found sufficient to drive piles in the upper clay of the Chicago subsoil,* and cap these, with concrete footings supporting the column bases.

Fig. 3 shows the foundations of the northeast corner of the building, comprising the most elaborate part of the foundations. At this corner the footing of an adjacent building spreads far out into the building lot, as shown in the detail section A in Fig. 3; cantilever girder footings had there-



Transverse Section at Stage,

*Instead of sinking concrete piers through the clay strata to hardpan or rock, as is the modern practice in constructing office buildings in Chicago.

fore to be used to support the wall columns at two bents, especially as heavy loads concentrated here As is shown by the detail AB in Fig. 3, the columns rest on these girders by riveted footings. The wall columns to the rear of this portion have simpler footings, as shown for Cols. 5, 6 and 7 in the detail section CD. The loads here were such

It should be stated here that the walls of this building are carried by wall girders attached to the columns, in full "cage" construction, except in the front wall above the third floor. A change in the window spacing above this point, which would have necessitated offsetting the columns at the third floor, made it simpler and cheaper to

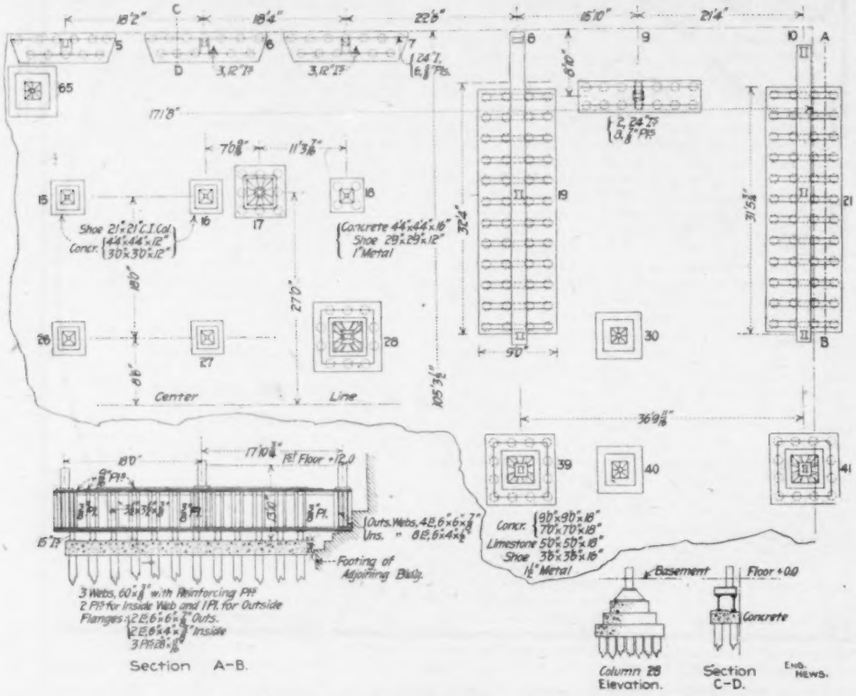


FIG. 3. FOUNDATIONS IN NORTH-EAST CORNER, ORCHESTRA HALL.

that a single row of piles would have sufficed; but for better stability an inner row was added, and short crossbeams on the two main grillage beams transmit a small part of the load to the inner row.

The remaining main column foundations are square piled foundations, as represented by Col. 28. This column, it may be noted, is one of the two columns KS (Fig. 6) which form the central

carry the remaining four stories of wall directly on heavy lintel girders at the third floor level; correspondingly, the floorbeams in this section are wall-bearing at their outer ends.

The heavy foundations under the front (east) section of the structure are due partly to the fact that they carry the front wall and the transverse fire wall, and partly to the fact that there is an unobstructed foyer the full width of this part of

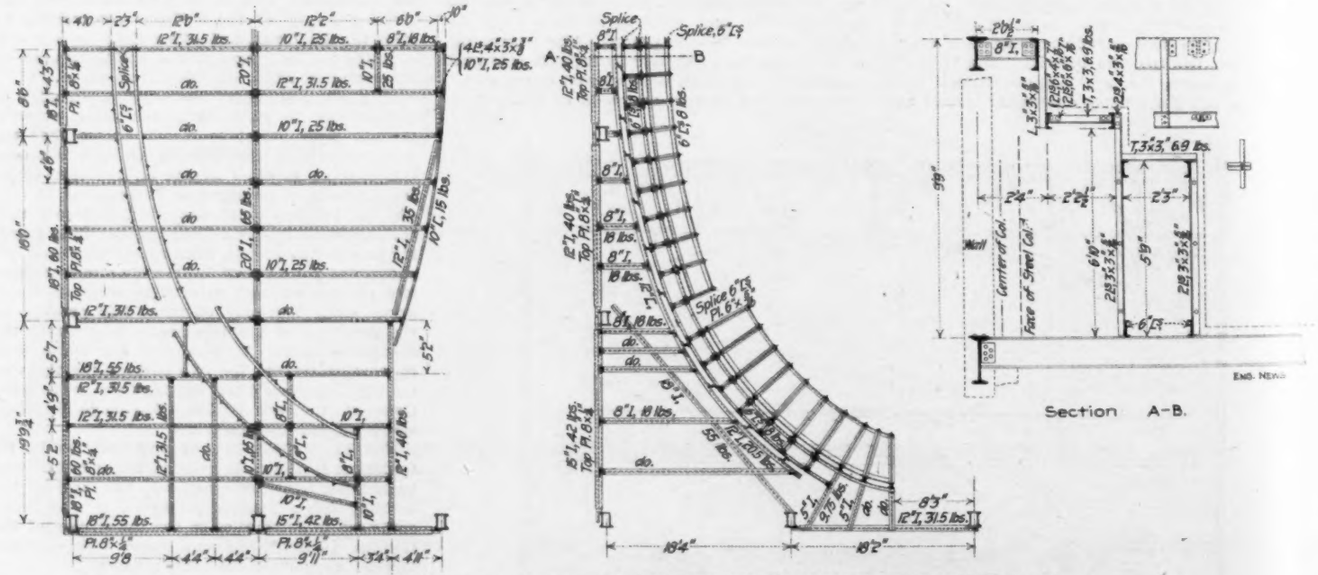


FIG. 4. FRAMING OF MUSIC-PLATFORM AND CHORUS-BANKS, ORCHESTRA HALL.

supports of the overhung tiers. The short one-story columns under the parterre, which support only that floor, required no piles, but have the concrete footing block resting directly on the clay. Pressures of 1½ tons per square foot were allowed on this material.

the building, which necessitates transferring the loads from the center line of columns above the third floor to the front and rear columns of the part of the building in question.

ORCHESTRA AND CHORUS.—The space that in the ordinary theater is occupied by the stage is here required merely to accommodate the musicians and the chorus singers. No overhead work being necessary, the simple roof construction exhibited in Fig. 1 is used. The roof is carried by transverse trusses, as already explained, and a curved sound-reflecting ceiling continues the line of the auditorium ceiling downward until it merges into the rear wall.

The orchestra or music platform has a flat floor involving nothing unusual. Circling around the back of the platform rise the chorus banks, framed as shown in Fig. 4, of angles and channels. The filling between the framing is of concrete, as is the case throughout the auditorium portion of the building. The office building floors and the roof over the auditorium are constructed of terra cotta flat arches.

BOX FLOOR.—Of the three suspended floors, the box floor is much the simplest. This is due to several facts: (1) the floor is practically flat and level throughout; (2) the radial length is not as great as that of the balcony floor; and (3) the partitions between the boxes extending relatively near to the front made it possible to support the front portion of framing by suspenders concealed in these partitions and hung to the balcony framing above. An idea of the difference in conditions between this floor and the balcony is obtained by noting that column KS, on the back line of the box floor, is one of the two main forward balcony supports (see Fig. 6), although the balcony railing is directly above the box railing.

As it was possible to locate the suspenders quite close together laterally, the main floor girders could be arranged so as to render secondary floor beams unnecessary. The simple framing that resulted is shown in Fig. 5. The floorbeams are radial, each being anchored to columns or to transverse floorbeams at the rear end, and supported by a suspender near the front. In the forward corners, along the sides, the framing is modified because the cast-iron column KH, required for supporting the balcony floor, is available. A radial double girder cantilevered on this column is used to support the outer end of a double girder extending into the extreme forward corner; auxiliary radial cantilevers supported by this latter girder furnish the intermediate framing. This arrangement is much like that in the corresponding corner of the balcony, described below, except that the box floor is flat while the other is inclined.

The flat floor introduced one special feature in the corner framing: the intersection of the sec-

ondary radials with the double carrying girder. In the balcony floor these radials could be dropped below the girder and supported by a riveted gusset connection. In the box floor the radials are flush with the girder, and to enable them to cantilever across the girder it was necessary to use long

...nge plates over and under the intersection. The ...tail plan shown above the main framing plan in ...g. 5 and the sketch "Detail at L-L" make the ...esign clear.

The forward edge of this tier of framing ex...bits a special detail which secures an excep...nally shallow floor for a narrow strip along the ...ge, the upper surface of the floor being formed ...to a slight step to correspond. The detail sec...planation in addition to the plan, Fig. 6. It should be stated that the floor filling between the beams is concrete, 4 ins. thick, which is molded to the general slope of the balcony and on which the stepped work, made of concrete slabs, is later placed. The concrete filling rigidly ties together the whole framing.

Special details, however, occur at the lower end of the balcony. Here the allowed floor thickness was only 10 ins., and the radial girders, as well as the intermediate work, had to be kept safely within this limiting depth. The way in which the main girders were detailed to meet this condition is made clear by the elevation in Fig. 6. Each component I-girder terminates at the bottom in two 6-in. channels back to back, riveted to an extension of the main web plate and extending out horizontally in cantilever fashion to the curb, a net projection of about 3 ft. The curbing of the floor is a 6-in. channel. This curb channel is insufficient to carry the entire floor load between the girders. In the middle of the panels, therefore, auxiliary cantilever beams C, D and E project from the last line of floorbeams to support the curb channel. Details of these cantilevers are shown in Fig. 7. The cantilevers C and D are supported only by the last full floorbeam, which is a double beam composed of two 15-in. channels spread 12 ins.; cantilever E is also fastened to these channels, but in addition extends back another panel and finds its anchorage in the second main floorbeam, which is a heavy 20-in. plate girder, and which also carries the box floor suspenders B.

The framing of the extreme forward corners of the balcony floor is somewhat similar to the above-described framing of the main central portion, but necessarily is much more irregular. On each side is a main radial girder, H (shown in detail in Fig. 8), supported on a short cast-iron column (KH) and anchored by one of the principal wall columns. Here again the ratio of overhang to total length is much over one-half. A double

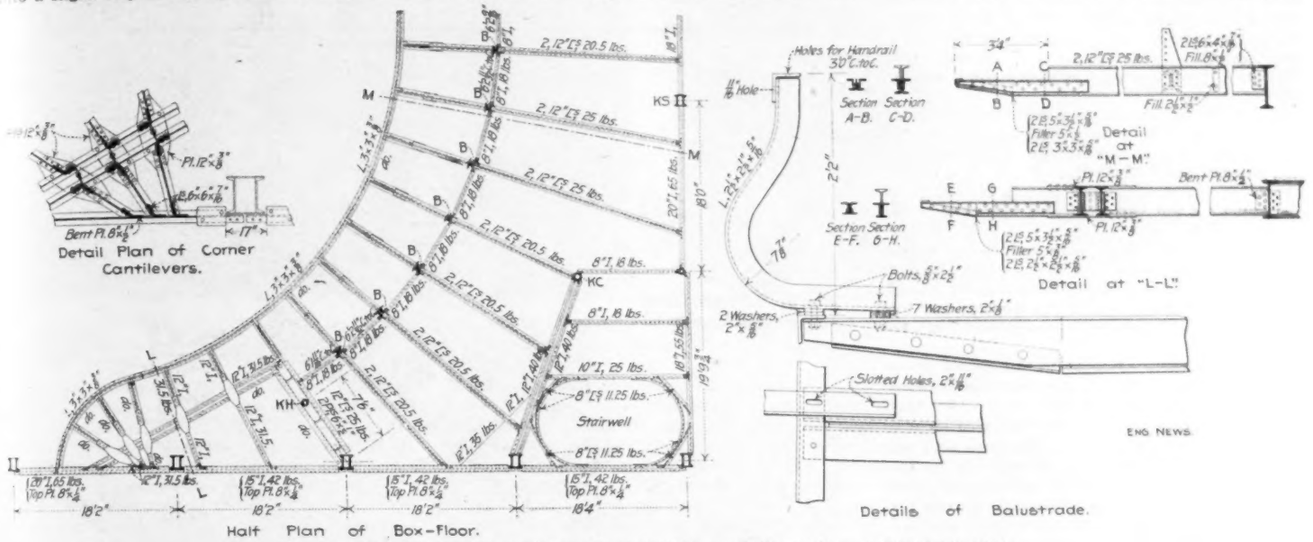


FIG. 5. HALF-PLAN AND DETAILS OF FRAMING OF BOX-FLOOR, ORCHESTRA HALL.

tions in Fig. 5 show the construction: the 12-in. channel floorbeams extend only to 2 ft. 4 ins. from the edge, and for 12 ins. back of this they have the upper 6 ins. of depth cut away. Two 6-in. angles riveted to the web of the channels cantilever out the remaining distance, and these angles themselves are cut away in the forward portion so as to give a depth of less than 3 ins. at the curb. This sheared edge, however, is reinforced by 3 × 3-in. angles riveted along the sides of the 6-in. angles.

The curb along the front of this floor is made of one 3-in. angle. The balustrade surmounting the curb is also a horizontal 3 × 3 × ⅜-in. angle, supported by curved angle posts bolted to the floorbeams. A detail is given in Fig. 5. The same balustrade construction is used also for the balcony and the gallery.

BALCONY FLOOR.—The general disposition of the balcony floor is explained by the architect's plan in Fig. 2. The steel framing is shown in Fig. 6. The central feature of this framing is the set of four radial longitudinal girders, 50 ins. deep at their deepest part; two of them lie on each side of the center line. These girders, each of which consists of two parallel plate girders of I-section, connected by plate diaphragms, are supported by columns (KS and KC) at a point less than half their length from the rear end, and cantilever the remaining part of their length. The rear ends of the girders are framed into 30-in. transverse girders, which serve as anchorage. Fig. 7 shows one of the radial girders in detail elevation and plan.

The main radial girders support not only the balcony floor, but also, by means of the one-story cast-iron columns KG, nearly the entire weight of the gallery floor above, and, by means of the suspenders B attached to intermediate floor-beams, a large part of the load of the box floor below, as has already been explained. The overhang of the radial girders, beyond center line of supporting column, is 25 ft. 1 in. in the case of each girder of the outer pair, and not less than 30 ft. 4 ins. in the case of the middle pair! The latter rests on a steel column (KS in Fig. 6), while the former is carried by a cast-iron column (KC). The two columns KS were made of square section, in steel, because they are located in the wall at the rear of the parterre, while columns KC, not being concealed in a wall, were preferred of round section and were therefore made of cast iron.

The floor framing subsidiary to these radial girders is, generally, simple and requires no ex-

floorbeam (J) of two 15-in. channels rests on this radial girder at one end, and on the wall framing at the other end. It extends along the whole length of the corner and provides support for a number of radial cantilevers, which reach out far enough to carry the 6-in. channel curb. These cantilevers are each composed of two 6-in. channels; the two longer cantilevers are bent to fit the lines of the floor, while the three short ones are straight and level.

As the floorbeams of the balcony floor at its intersection with the side wall find support on the wall framing, it is worth noting that the wall girders themselves are in all cases level. The wall ends of the floorbeams, therefore, are in most

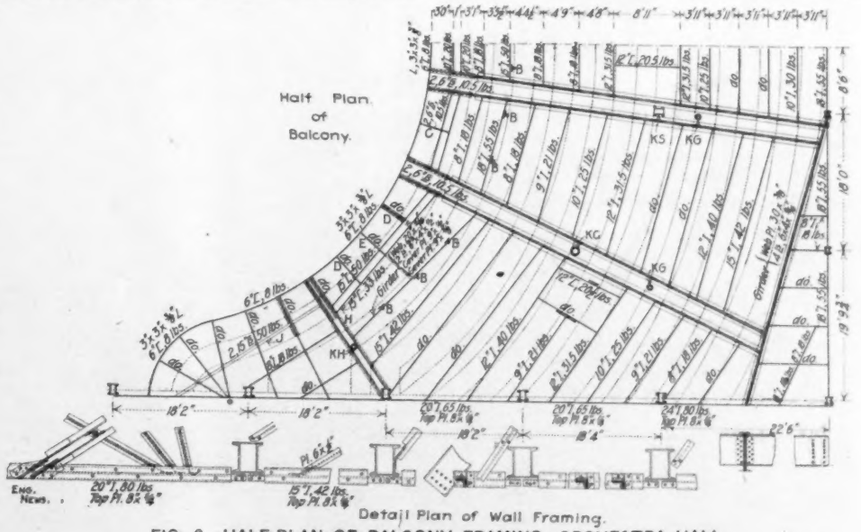


FIG. 6. HALF-PLAN OF BALCONY FRAMING, ORCHESTRA HALL.

cases supported by posts made of single angles, which posts foot on the wall girders. The detail plan of the wall work in Fig. 6 indicates these posts. They are steadied laterally by the wall masonry.

GALLERY FLOOR.—The framing of the gallery floor, Fig. 9, follows in its arrangement that of the balcony, but is much simpler. The main radial girders, of which there are four (two each side of the median line), are not only much

shorter than those of the balcony, but have a much smaller ratio of overhang, due to the fact that the front line of the gallery is considerably back of that of the balcony. These girders, which are supported by the cast-iron columns KG already noted, are each composed of two channel-shaped plate girders tied together by diaphragms, and as shown in the elevation, Fig. 10, they have a middle inclined and an upper horizontal part connected by a large gusset plate. Due to the fact that these girders are cantilevers, the moment at this riveted connection is not very large, even with the most unfavorable distribution of live load.

The lower end details are similar to those of the balcony floor. The main girders are extended by channel cantilevers in precisely similar manner, and the auxiliary cantilevers, M, N, P, Q and R, of which details are shown in Fig. 10, are much the same as the corresponding elements in the balcony floor.

The framing of the forward corners of the floor is not as complex as in the balcony floor, because the front line of the gallery is only slightly curved. An inspection of the plan in Fig. 9 shows how this avoids the complicated corner work of the balcony.

The wall girders adjacent to the gallery framing are level, as in the balcony floor, and the floor-beams are supported by angle struts where their levels differ from those of the wall girders.

CONSTRUCTION WORK.—Orchestra Hall was designed by the firm of D. H. Burnham & Co., Architects, Railway Exchange Building, Chicago, and is being built by the Thompson-Starrett Co., of Chicago and New York, Mr. George Simpson, Chief Engineer. The steelwork was detailed and fabricated by the American Bridge Co., Philadelphia, Pa.

The erection of this building was characterized by extremely rapid construction, especially in the erection of the steelwork. The detail drawings for that work were commenced on June 15, 1904, and the structure was practically complete on the 1st of October. This rapid progress is the more notable an achievement because of the intricacy of the work.

Work on the site was commenced May 2, 1904. Several old buildings required to be torn down before the excavation could be begun. The removal of these buildings, excavation of the site, driving of foundation piles and placing concrete footing blocks for the column bases occupied a period of just three months. By August 2 the column footings were nearly ready for the erecton of the steelwork. This latter was begun in the week following. The view reproduced in Fig. 11 shows the condition of the work on August 9, when the basement columns had been set and nearly the whole parterre tier of beams erected. Four weeks later the roof framing of the auditorium was nearly up, as seen from Fig. 12, taken on September 6. The long side wall columns of the auditorium had been set, the connecting wall girders put in, and some of the roof trusses lifted into position. These trusses were shipped in two halves, riveted together on the ground in a position just beneath their final location, and thence hoisted to the top of the columns by a long double gin-pole or gallows frame, which is well shown in the view. Much work had already been done on the front portion of the building, but the architects now desired to concentrate the work on the auditorium portion, to make sure that this would be completed on time for the opening as planned, by the end of November.

Two weeks later, the interior framing of the auditorium was nearly completed, as evidenced by Fig. 13, a view taken on September 21. The view is on the balcony tier and shows the framing of this tier and of the gallery above. The side wall brickwork was also going up rapidly this time, having reached a point nearly level with the top of the balcony; the scaffolding in the back-ground in Fig. 13 serves for the mason work of the south wall, and a portion of the north wall scaffold is visible in the extreme foreground.

By October 1st the steelwork, as already stated, was practically completed. Fig. 14, a view taken on October 4, shows the appearance of the structure about this time. At present the date of formal opening is placed at December 2 of this year, and the Thompson-Starrett Co. feel absolutely certain that it can meet this date.

Thus, the entire work on the structure will be comprised in a period of seven months, and the steelwork, including the making of detail drawings, within a period of less than four months.

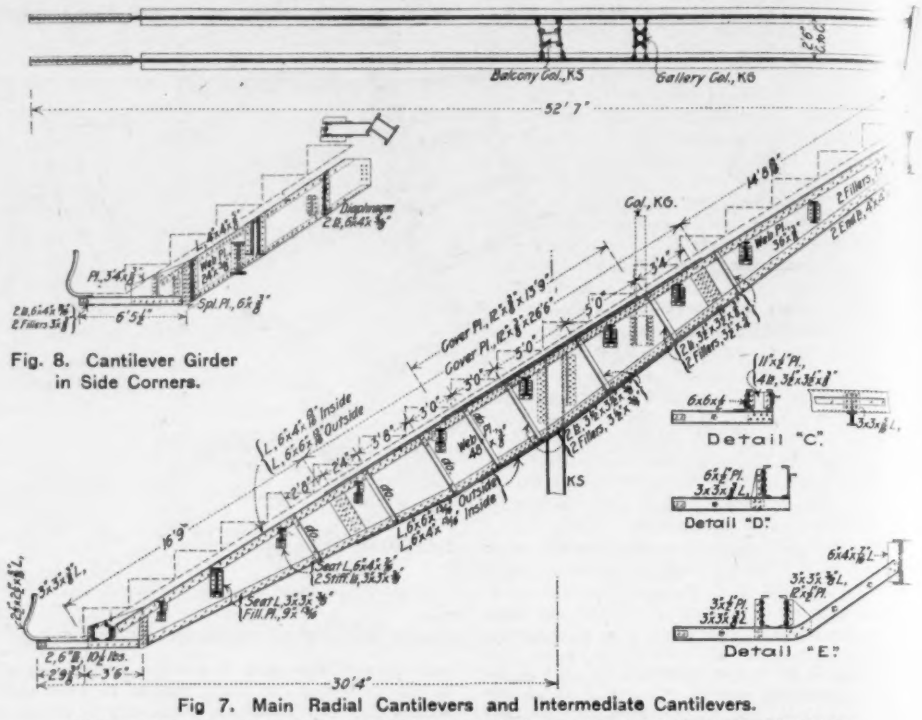
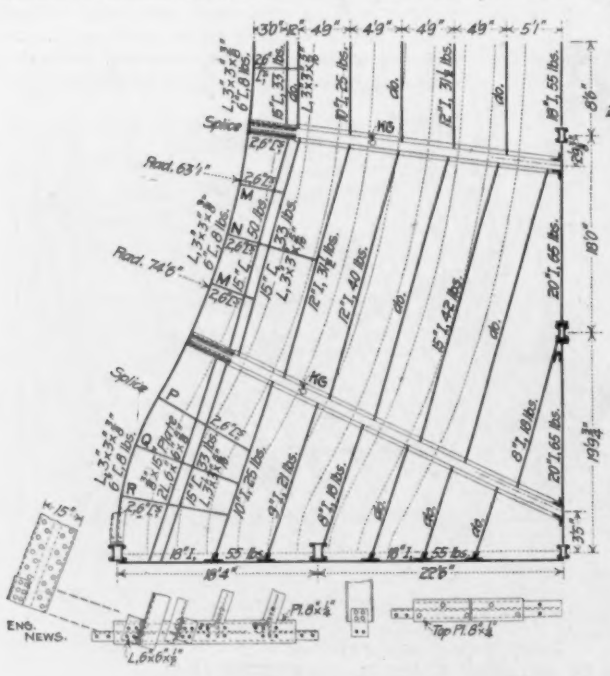


Fig. 8. Cantilever Girder in Side Corners.

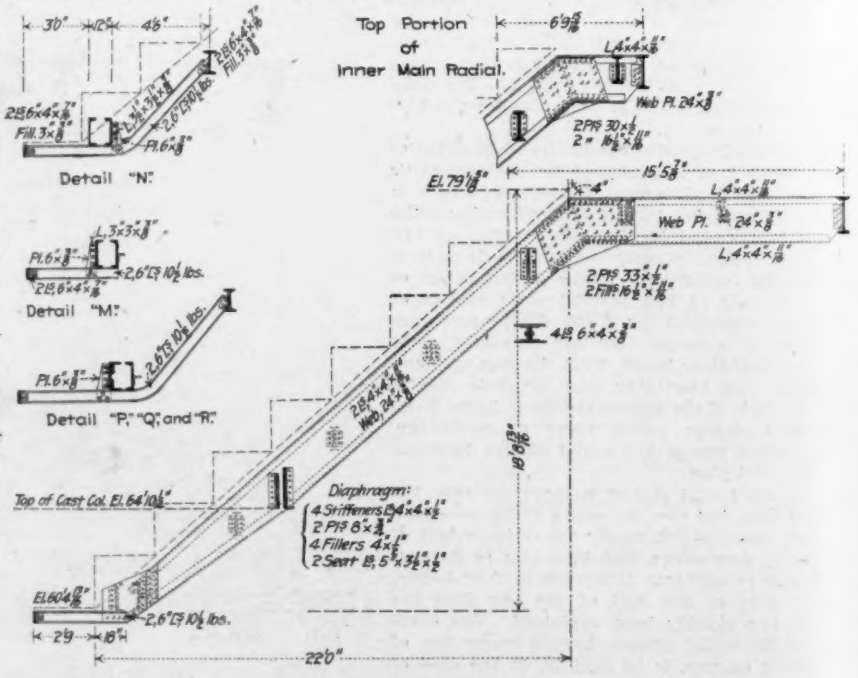
Fig 7. Main Radial Cantilevers and Intermediate Cantilevers.

FIGS. 7 AND 8. DETAILS OF BALCONY FRAMING, ORCHESTRA HALL, CHICAGO.



Detail Plan of Wall Beams

FIG. 9. HALF-PLAN OF GALLERY FRAMING.



Side Elevation of Outer Main Radial.

FIG. 10. MAIN RADIAL CANTILEVERS AND INTERMEDIATE CANTILEVERS.

FIGS. 9 AND 10. FRAMING OF GALLERY, ORCHESTRA HALL, CHICAGO.

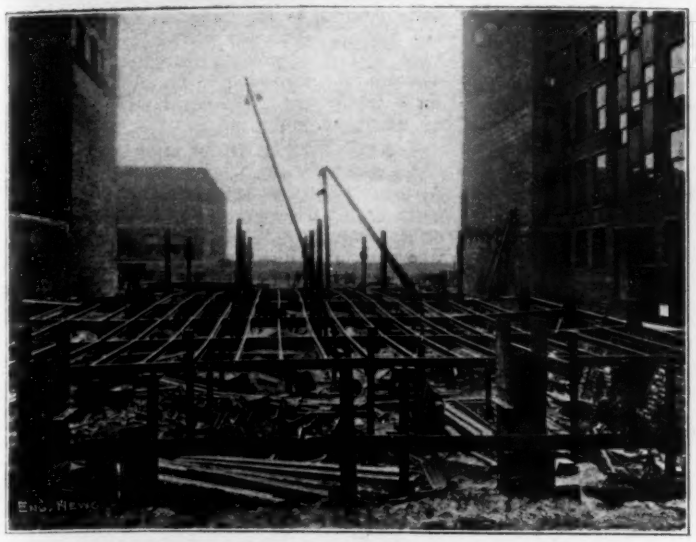


FIG. 11. VIEW OF ORCHESTRA HALL SITE ON AUGUST 9, 1904.
View Taken from Rear of Site, Railway Exchange Bldg. at right, Pullman Bldg., at left, Art Institute in back-ground. The doubly-curved floor is the parterre tier.

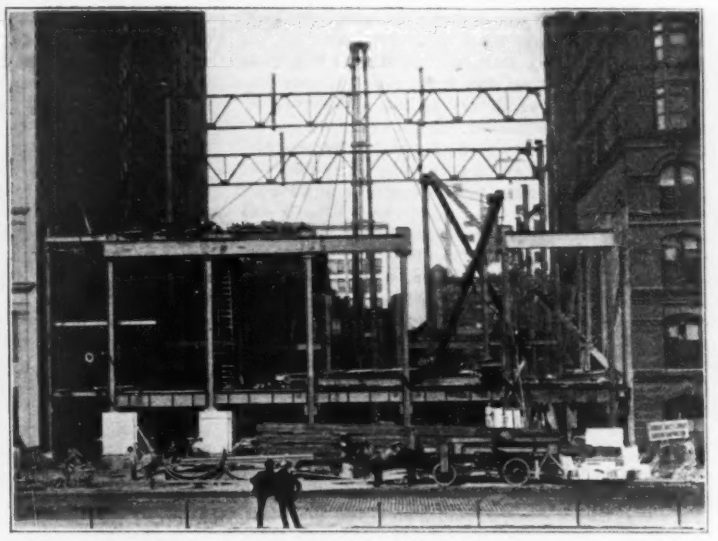


FIG. 12. CONDITION OF WORK ON SEPTEMBER 6, 1904.
View from front. Auditorium roof trusses being placed.

LOADS AND STRESSES.—The loads and stresses assumed in the design of this building were as follows:

Floor load, office building; 150 lbs. per sq. ft. on all floors. Floor load, orchestra hall: Main floor and box tier, 150 lbs. per sq. ft.; balcony and gallery, 180 lbs. per sq. ft. Roof load: 100 lbs. per sq. ft. These are all total loads. Unit stresses: Rolled beams, 16,000 lbs. per sq. in., extreme fiber stress; built up girders, 14,000 lbs. per sq. in., flange stress, and 10,000 lbs. per sq. in. shear; columns and struts, 15,200 — 58 l ÷ r; tension members of roof trusses, 16,000 lbs. per sq. in.

AMERICAN MEETING OF THE BRITISH IRON AND STEEL INSTITUTE.

That influential technical society, the Iron and Steel Institute of Great Britain and the World, is at present on its second visit to the United States. During the 35 years of its existence (the society was founded in 1869), it has paid one or more official visits to nearly all of the European countries: Belgium, France, Germany, Austria, Spain, and Sweden; but only once before this year has it come to America. That was in 1890, when it held its regular annual autumn meeting in New York City, and made an excursion to the most important metallurgical plants in the eastern part of the United States. The second visit, now under way, is arranged much like the first. The annual meeting was held in New York City on Wednesday, Oct. 26, and this is followed by a circular tour passing through Bethlehem, Philadelphia, Washington, Pittsburg, Cleveland, Conneaut, Buffalo, and Niagara Falls, Albany and Schenectady, and thence back to New York. A section of the visiting party also makes a side trip from Pittsburg to St. Louis and Chicago.

There is, as yet, no technical society in America corresponding in scope to the Iron and Steel Institute. In consequence the latter has quite a number of American engineers and metallurgists in its list of members. It has therefore been easy to arrange very fully at the different stopping points of the tour for the entertainment of visitors. Local committees at the various cities in question have taken the arrangements in charge, and it appears that the visitors will have little lost time to record.

The New York meeting comprised two sessions, held in the concert room of the new Hotel Astor on the morning and afternoon of Oct. 26. At the morning session the President, Mr. Andrew Carnegie, was in the chair, while at the afternoon session Mr. E. Windsor-Richards, one of the Vice-Presidents, presided. Beyond the announcement that Mr. R. A. Hadfield is to be the next president of the Institute, the two sessions were occupied wholly by the reading and discussion of technical papers. These are briefly considered in the following:

DRY-AIR BLAST FOR BLAST FURNACES.

The first paper, "The Application of Dry-Air Blast to the Manufacture of Iron," by Mr. James Gayley (New York), claimed close attention and

FIG. 13. INTERIOR VIEW ON SEPTEMBER 21, 1904.
View at level of center of balcony floor. Gallery floor shown above.

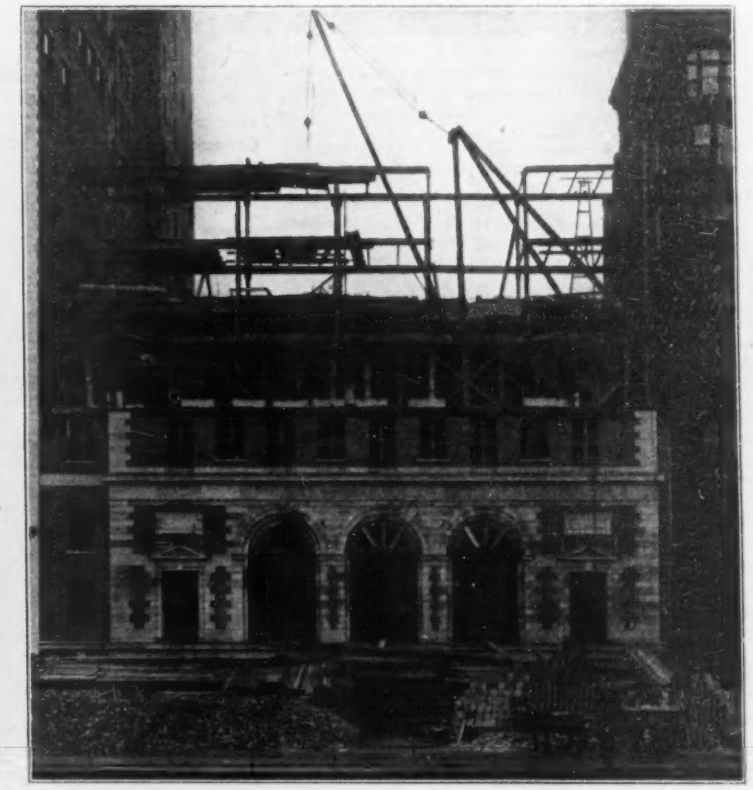


FIG. 14. VIEW OF ORCHESTRA HALL FROM FRONT, OCTOBER 4, 1904.
Erection of steelwork nearly completed.

great interest. As many of our readers will recall, Mr. Gayley is now First Vice-President of the United States Steel Corporation, and is this year President of the American Institute of Mining Engineers. His paper describes the successful attempt to desiccate the air supplied to a blast-furnace, in order to render the operation of the furnace independent of the great variations of atmospheric moisture. It happens that this variation is the greatest variation which affects the elements entering into iron smelting. The ore and the coke are kept within 10 per cent. of uniformity in chemical composition, while the atmospheric moisture varies 20 to 100 per cent. on successive days, or even on a single day. Moreover, aside from its variability, the quantity of moisture in the blast is harmful to the working of the furnace because it requires a large amount of extra heat to raise it to the furnace temperature. If the specific heat of the blast were zero, the variations in temperature from point to point within the furnace would be a minimum; as the contained moisture raises the specific heat, it makes these variations greater, and hence, for the same maximum temperature, lowers the average temperature of the furnace. It follows that the moist air-blast makes necessary a greater fuel-ratio and a reduced melting capacity. At Pittsburg the average moisture content of the atmosphere, at the Weather Bureau office, is 3 to 4 grains per cubic foot, which, in the case of an ordinary blast-furnace, means about 125 to 150 gallons of water entering the furnace each hour. At the furnace the air is likely to average one to two grains higher than at the Weather Bureau. Some detailed tables of moisture content in the air near the furnace, for each hour throughout two different months, are given in the paper. They show variations, frequently reaching 25 per cent. in a few hours, sufficient to draw heavily on the reserve heat held by the furnace and therefore seriously affect the quality of metal produced. The extra manipulation required to overcome the resulting irregularities, of course, reacts on the quantitative output.

After considering and trying various methods for getting rid of the moisture in the air-supply, the refrigeration progress was selected, and a plant therefor was designed to be put in at the Isabella furnaces, at Etna, near Pittsburg, Pa. A small refrigerating plant was first built, to yield experimental data as to required capacities, and then the plant for the furnace was designed. The plant was designed on the cold-brine system, to avoid danger of accident from using ammonia directly in the coils. The plant comprises the following main items:

Two compressors, York Mfg. Co., York, Pa.; steam cylinders 28½ and 56 ins., compressor cylinder 22½ ins., common stroke 36 ins. One compressor for reserve. Capacity of each compressor, 225 tons ice-melting per day.

Brine tanks: Coils of concentric 2-in. and 3-in pipes; calcium chloride brine of sp. gr. 1.21 flows into top of tank, is pumped from bottom and thence into the 2-in. pipes of the coils.

Refrigerating chamber: 4,500 2-in. pipes, 20 ft. long, 60 columns each having 75 pipes; the chamber is divided into three sections one above the other; it is lined on the inside with 2-in. plates of compressed cork; air is forced through the chamber by a centrifugal blower, to avoid excessive suction in blowing engine; two electrically-driven fans below refrigerating chamber are provided to distribute the air in passage through the chamber. The coils are divided into sections which can be cut off from remainder and hot brine circulated in them to melt off the frost. In practice one-third of all the coils are melted each day, so that each section runs three days.

The plant was put into service on Aug. 11, 1904, the furnace then using an ore-mixture of 50 per cent Mesaba ore and 50 per cent. soft Michigan hematites. No change was made other than using the dry-blast instead of the natural air. The furnace is 21 ft. diameter in the bosh, 13 ft. 6 ins. at the hearth, and 14 ft. at the top; its height is 90 ft. The air supply was gradually changed from natural air to dry-blast, and the charge of ore was also increased gradually. On Aug. 11, before using dry-blast, and on Aug. 25, with full dry-blast, the respective burdens were:

	Aug. 11. lbs.	Aug. 25. lbs.
Coke	10,200	10,200
Ore	20,000	24,000
Stone	5,000	6,000

The output of the furnace increased from 358 tons per day, average between Aug. 1 and Aug. 11 to 447 tons average between Aug. 25 and Sept. 9; in the same period the coke-consumption per ton of iron fell from 2,147 lbs. to 1,726 lbs.

Days of excessive humidity remained without effect on this furnace, while a neighboring furnace required extra charges of coke to counteract the effects of the humidity.

The effect of the refrigerating chamber directly was as follows: during a period of 13 days the average moisture in the atmosphere was 5.66 grains per cu. ft.; the average in the dried air was 1.75 grains.

The blowing engines had to be slowed down from 114 r. p. m. to 96 r. p. m., reducing the volume of air from 40,000 to 34,000 cu. ft. per min. Yet the output, as above shown, increased 89 tons, and 1 per cent. more coke was burned. The blast was 150°F. hotter than before. The average temperature and composition of the gas changed as follows:

	Before.	After.
CO	22.3%	19.9%
CO_2	13%	16%
Temperature	538°F.	376°F.

The lower temperature of the gas means more heat utilized in the furnace. Another saving is in waste ore dust, which has been cut down from 5 per cent. to less than 1 per cent. of the ore charged.

The paper was discussed by Messrs. E. Windsor Richards, R. W. Raymond, E. P. Martin, John Fritz, E. S. Cook, A. Lamberton, E. H. Saniter, Axel Sahlin, and C. H. Morgan. The discussion added little or no information, but expressed the general interest in and approval of the new departure. The paramount importance of uniformity of moisture, as compared with low moisture, was emphasized by several. The liberality of the management, which made it possible to install such a large plant without certainty of advantageous results, aroused approving comment. Mr. E. S. Cook reported that he had some time ago worked out a plan for drying the air supplied to a blast-furnace, but with the use of calcium chloride as a drier; the process had figured out too expensive for use. Mr. A. Sahlin said that in operating a blast-furnace on Chesapeake Bay, some years ago, his thoughts had by necessity been directed toward supplying dry-air to the blowing engines, but instead of adopting artificial drying he had merely drawn the air from outside of the blowing-engine room, with results showing a slight improvement over the previous working.

STRENGTH OF STEEL AS A FUNCTION OF CHEMICAL COMPOSITION.

Mr. H. H. Campbell, of Steelton, Pa., presented an interesting paper on "The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel." In this paper he brought together the results of a very extensive and carefully planned series of experiments which had the object of showing definitely the influence of each of the elements noted upon the strength of the metal. Resulting from this, of course, are formulas giving the strength of steel as a function of the composition percentages. This entire line of thought and work is not new, but its development has been confined to two or three men, most prominently, Mr. Campbell and Mr. W. R. Webster. The present paper represents by far the most advanced work on this subject. We hope to present a full abstract of it in another issue.

In discussion, Mr. Webster, while highly commending the work reported in the paper, pointed out that it covered only part of the field of strength of steel, as heat treatment and amount of working have so much influence. Mr. Webster has previously proposed the plan of polishing a small spot of the metal and examining it under low magnification, to observe the size of structure. This, he believes, would give the additional information required for judging the strength and quality of the metal.

Mr. C. B. Dudley stated that for many years the Pennsylvania R. R. has made it a practice to closely examine all failures of parts in service, with most excellent results. This work, where usually both chemical and physical tests are made, has indicated a close correspondence between chemical and physical properties. The results obtained by Mr. Campbell have been used in the Altoona laboratory of the company for some time, and with great satisfaction, for example, where it was impossible to get pieces large enough for a tensile test. The paper was also discussed by Mr. R. W. Hunt and Mr. J. A. Mathews.

ABORIGINAL IRON METALLURGY.

A paper by Mr. C. V. Bellamy, entitled "The West African Smelting House," proved quite fascinating. It describes the iron-smelting industry of an uncivilized West African tribe of negroes, who work up a low-grade hematite ore into tool steel by what is virtually the old "direct process." The paper is reprinted on another page, and need therefore not be further noted here.

In discussing it, Prof. H. Bauerman expressed the opinion that probably all over the world the production of steel preceded the production of iron. The use of natural draft in this West African steel-furnace is notable. The use of manganese oxides, rather than iron oxides as in this case, characterized some of the early iron-smelting.

Dr. James Douglas remarked that the early metallurgical artisans achieved remarkable results in quality, even though they worked with very small quantities. This is illustrated in Mr. Bellamy's paper; the analyses of the slags show very small loss of iron. In some parts of Spain great slag heaps are still seen, relics of an early copper industry; these slags have often been thought to be very valuable for their remaining metal, but as a matter of fact they are remarkably pure, showing even a lower metal content than modern slags. The same is true of most of the slag heaps found in Mexico. Sir James Kitson and Prof. H. M. Howe also discussed the paper briefly.

HIGH-SPEED TOOL STEEL.

An extended summary of the present-day development of "high-speed tool steel" was presented by Mr. J. M. Gledhill, under the title "The Development and Use of High-Speed Tool Steel." The paper gives the general results of many experiments made to determine the effects of the various alloying elements; it also explains the proper methods of manipulating the steel, in grinding, hardening, etc.; finally, it cites in detail many records of time-saving due to replacing ordinary carbon-steel by high-speed tool steel. We hope to give an abstract of this paper later.

One point made by the author was that for the best results it is necessary to use the purest Swedish or Dannemora iron. This assertion was questioned by many, Prof. H. M. Howe, Mr. H. H. Campbell, Mr. J. A. Mathews, among others. Prof. Howe called for actual experimental facts to verify the statement. Mr. Campbell said that the Pennsylvania Steel Co. makes several kinds of high-speed steel, but uses no Swedish iron whatever; he believes their results are as good as any. Mr. Mathews stated that the Crucible Steel Company of America has found pure American irons to be just as good for these special steels as Swedish iron.

Prof. H. M. Howe called attention to the fact that if high-speed steels are to outlast one or two generations, it will be necessary to draw on more common elements than tungsten, molybdenum and vanadium. Mr. J. A. Mathews remarked that the Crucible Steel Company of America has used hundreds of thousands of pounds of molybdenum, and its experience could therefore supply the information as to the effects of molybdenum, which Mr. Gledhill lacked. Mr. A. S. Pye-Smith remarked that the influence of manganese is not referred to in the paper, and asked whether any recent information on this matter is available. As Mr. Gledhill was not present, this and other queries remained unanswered. Mr. Pye-Smith also noted that proper treatment of the steel in forging, grinding and hardening is equally important with the old-type carbon steel and with high-speed steel. The letter-stamp often placed on the tool by the blacksmith is very apt to give occasion for a crack to start, and should therefore be omitted, or else carefully done. Mr. T. Westgarth, Prof. J. W. Richards, Mr. Oberlin Smith and Mr. W. Carter also spoke. The effect of the new steels on machine-tool development was discussed somewhat, but with no general agreement. Mr. Smith

lieved in the ultimate substitution of milling for planing, preceded by the development of planers having moving tools like armor-plate planers, while Mr. Carter states that, on lengths of 10 ft. or over, the planer easily beats the milling machine. An example is a 7-ft. planer running at 65 ft. cutting and 150 ft. per min. return, taking ½-in. cut by ⅛-in. feed, and driving high-speed tool steel to its limit of durability.

A paper by Prof. H. Bauerman, on "Iron and Steel at the St. Louis Exposition," was read in abstract by the author, without discussion. The paper will serve as a guide for those visiting the exposition.

Three other papers were "taken as read." They were: "Acid Open-Hearth Manipulation," by Messrs. A. McWilliam and W. H. Hatfield; "Comparison of Methods for the Determination of Carbon and Phosphorus in Steel," by Messrs. H. J. von Jonstorff, A. A. Blair, G. Dillner, and J. E. Stead; and "The Utilization of Exhaust Steam by Steam Accumulators and Low-Pressure Rateau Turbines," by Mr. E. Demenge. The subject discussed in the last of these papers has already been noted in Engineering News of Sept. 29, p. 282.

THE TIME REQUIRED TO RAISE STEAM FOR FIRE PUMPS FROM COLD BOILERS AND THE COST OF BANKED FIRES.

Starting with cold boilers, of the type generally used in New England textile mills, it takes about 1½ hours to get up 50 lbs. of steam, or enough to run a fire pump. A well-banked ordinary factory boiler can be relied upon to promptly operate a fire pump at the rate of 1,000 gallons per minute. Banking such a boiler so as to maintain a gage pressure of 50 lbs. need not require more than 800 lbs. of coal per day, costing about $1.60, for fuel, at most points in New England. It is advisable that the steam pressure be maintained at 40 to 50 lbs. per sq. in. where fires are banked or at a point, say, 10 lbs. higher than required for starting the fire pump so as to give some margin to draw on while fires are being opened.

These, in brief, are the conclusions drawn from tests made by inspectors of the Associated Factory Mutual Fire Insurance Cos., at the request of Mr. John R. Freeman, M. Am. Soc. C. E., President of certain of these companies, and reported on under date of Aug. 31 by C. H. Phinney and E. V. French, Inspectors. The tests were made during an investigation of the water and fire departments of Fall River, Mass., to determine whether it would be safe for the mills to allow the fires to be drawn from their fire-pump boilers during a shut-down of their mills, and thus depending wholly upon the city water and fire departments for fire protection. It may be said here that, although the water and fire departments were found to be unusually strong, the inspectors did not consider that it would be advisable to draw the fires, particularly in view of the small expense required to keep them banked.

TIME REQUIRED TO RAISE STEAM FOR FIRE PUMPS FROM COLD BOILERS.

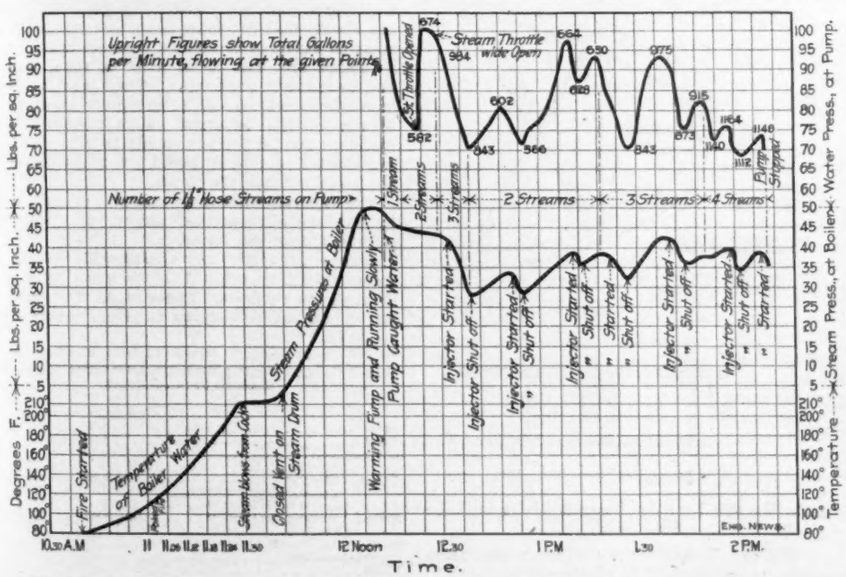
The most thorough-going of the tests, or at least the one most fully reported, was made at the mill of the Union Manufacturing Co. Here one boiler out of a battery of nine, none of which had been fired for two weeks, was chosen. The day on which the test was made "was rainy and muggy, the temperature of the air 79°F." The fire was kindled with waste paper and about one-eighth of a cord of sound native pine, 2 to 4 ins. in diameter and 4 ft. long. The fire was lighted and handled in the ordinary manner by one of the mill firemen. The temperature of the boiler water before starting was 84°F.

The boiler was of the ordinary horizontal tubular type, 5½ × 20 ft., with 75 3½-in. tubes, a grate 5½ ft. square and a rated capacity of 125 HP. As there was no means of subdividing the main steam drum of the battery, all of it and of the pipe leading to it had to be heated. The accompanying diagram shows the results obtained with both the boiler and the pump.

A 1,000-gallon Deane underwriter pump was used, 18½ × 10¼ × 12, located near by, and having a 4-in. connection with the main boiler drum. For the fire streams, four 50-ft. lengths of ordinary 2½-in. rubber-lined hose, each with a 1⅛-in. nozzle, were attached to the pump outlets. All the hose lines were left open until the pump picked up water, then the fire streams were manipulated, as shown on the diagram.

At the Granite Mills two boilers in different mills were tested, with the widely varying results shown in the summary given below. Each of these boilers was of the horizontal, tubular type, 5 × 18 ft., with 76 3¼-in. tubes and 25 sq. ft. of grate area. Each boiler was one of a battery and had a companion boiler with a banked fire and about 50 lbs. steam pressure, thus giving moderately warm flues and chimney. Although No. 1 boiler required only 55 minutes and No. 2 required 2 hrs. 55 min. to raise 50 lbs. of steam, the two boilers were "supposed to be in about the same condition." As explaining the differences in results, the report says:

> It is stated that the draft in No. 1 boiler is better than in No. 2, and that in No. 1 Mill test soft coal was used entirely, while in No. 2 hard and soft coal mixed were used. Further, the No. 1 fire was said to be much less solid than No. 2, and probably less able to hold steam after 50 lbs. was reached. It was also stated that the No. 1 fireman is a cool, collected man, while the No. 2 fireman is more excitable, so that the No. 1 man probably handled the fire more skilfully under these special conditions. The results are interesting as showing how wide differences may result from apparently small variations in conditions and men.



RESULTS OF TESTS TO SHOW THE TIME REQUIRED TO RAISE STEAM FOR A FIRE PUMP FROM A COLD BOILER.

At the No. 1 mill of the Richard Borden Manufacturing Co. a test was made of one of several 84-in. ordinary upright boilers, having 353 2¼-in. tubes, 13 ft. long, and a grate area of 33 sq. ft. These boilers did not have brick settings and raised steam quicker on that account, the time required to attain 50 lbs. pressure being 1 hr. 10 min.

Bringing together the results of the four tests we have:

	Hours.	Minutes.
Granite Mill, No. 1	0	55
Richard Borden Mfg. Co.	1	10
Union Mfg. Co.	1	30
Granite Mill, No. 2	2	55
Average, about	1	30

Commenting on these figures, the report states:

> It is believed that these tests fairly represent the conditions likely to be found in average mutual mills, and show that under the usual conditions steam could not be raised from cold boilers quickly enough to save the ordinary mill plant in case of fire. The Union Mill test also suggests the desirability, if ever it is necessary to get up steam to fight a mill fire, of starting at least two boilers, so that the total amount of boiler fire may be greater and the heating up of the settings quicker and so that, when steam is obtained, there will be an ample supply to run the fire pump at once.

ABILITY OF A BANKED FIRE TO QUICKLY FURNISH STEAM.

A boiler at the mill of the Union Manufacturing Co., in the same battery as that containing the boiler tested as to time of raising steam from a cold boiler, was tested with a banked fire. At the time of the test the fire had been banked for a week and had not been cleaned for 24 hours. A steam pressure of 50 lbs. was being maintained.

Four 50-ft. lengths of rubber-lined cotton hose, each fitted with a 1⅛-in. nozzle, were attached to the pump connected with this boiler. The day was sunny, with a good southeast breeze.

At a given signal the pump was started and simultaneously the fireman opened his drafts and began to stir his fire vigorously. The suction pipe was long and had no foot valve. After priming the pump was run at 70 to 80 revs. per min. for 4½ minutes before water reached the pump chambers. The speed was then reduced to 60 or 70 revs. per min., the water pressure being 20 to 40 lbs., after which some eight minutes were required to clear the cylinders of air and get four clean fire streams. Altogether, about 13 minutes were consumed in obtaining these streams. At the end of that time the boiler pressure had fallen from 50 to 42 lbs. It dropped, during the next 10 minutes, to 33 lbs., then came up to and remained at 40 to 43 lbs. throughout the remaining 45 minutes of the test. The pump made 70 to 80 revs. per min. during the latter period, with a water pressure of 70 to 80 lbs., and a delivery of 1,120 to 1,200 gallons per minute. Evidently these conditions might have been maintained for hours.

COST OF MAINTAINING 50 LBS. STEAM WITH BANKED FIRES.

Three mills were tested under the direction of Mr. T. G. Estes to determine how much coal would be required to maintain 50 lbs. of steam with banked fires. In addition, some records were obtained from a fourth mill.

At the Durfee Mill a horizontal tubular boiler in a brick setting was tested. The boiler was 6 × 18 ft., with 140 3-in. tubes and a grate area of 36 sq. ft. Pocahontas soft coal was used for fuel, and ordinary conditions were maintained. There was practically no radiating surface outside of the boiler setting. For a run of two weeks an average of about 460 lbs. of coal per 24 hours was used. During the following week steam was let into the header or drum for two days, with an average of 700 lbs. of coal per day for those days.

At the Arkwright Mill a Cahall vertical water tube boiler was tested. The main boiler was 80 ins. in diameter. The boiler had 108 4-in. tubes, 22 ft. long, and 48 sq. ft. of grate area. With fire over half the grate and ashes over the other half, the average coal consumption was 1,500 lbs. per day. With the fire over the whole grate for a week, the average fell to 838 lbs.

At Granite Mills, No. 1, a 5 × 18-ft. horizontal tubular boiler, with 76 3¼-in. tubes and a grate area of about 36 sq. ft., was tested. There was considerable radiating surface here, as the steam pressure was maintained on the 12-in. main drum, and up to the throttle and on the jackets of the

main engine. A mixture of about two-thirds soft and one-third hard coal was used. The average amount of coal used per day for two weeks was about 1,170 lbs.

At the mill of the Union Manufacturing Co. the mill record for a week, with steam up to the throttle valve of the engine, showed an average coal consumption of 732 lbs. a day.

The cost of the coal in the several tests ranged from $3.50 to $4.50 per ton. Assuming an average cost of $4 per ton, the four tests are summarized as follows:

Mill.	Average coal per day. Pounds.	Cost.
Durfee	458	$0.91
Arkwright	438 to 1,500	1.67 to $3
Granite	1,109	2.33
Union	732	1.46

Taking the smaller figures for the Arkwright test, the report states, the average for the four mills is 800 lbs. for coal per day at a cost of about $1.60. It is thought that little if any additional expense for a fireman would be needed to keep up a banked fire, since "the watchman could handle a slow fire of this kind."

A CONCRETE-LINED SHAFT FOR THE U. S. COAL & COKE CO.

By Francis Donaldson, M. E.*

The U. S. Coal & Coke Co., at Tug River, W. Va., has just completed two coal shafts which are noteworthy in being elliptical and lined with concrete. Both shafts penetrate two coal seams, the No. 4 seam at a depth of 100 ft., and the No. 3 or Pocahontas seam at a depth of 175 ft.

AIR SHAFT.—The air shaft is 14 ft. 2 ins. by 20 ft. in the clear, and is divided into two compartments by a line of 6 in. x 8 in. buntons carrying a brattice of tongued and grooved boards. One compartment is for an air passage; the other is to contain a spiral iron stairway. As this shaft is to be used as an upcast, and the rock penetrated is very solid, it was necessary to concrete it only for 45 ft. to cut off surface waters. At the point where it was decided to start the lining, bearing timbers were placed, and a foundation ring cut into the rock. A platform was built upon these timbers to support the first set of forms. The concrete was brought up in 5-ft. sections, the method being similar to that used in the hoist shaft, which is described below. The plans required the lining to have a thickness of 1 ft. This concrete was hand mixed.

When the surface of the bed rock was reached, the overflowing water was led to a point at one side of the shaft, where a small dam was built. A pipe was then placed from this dam so as to lead the water through the inner concrete form to the interior of the shaft. The concrete was tamped around the pipe, and, after it had set sufficiently, the pipe was plugged, thus completely cutting off the surface water.

HOIST SHAFT.—The hoisting shaft is 17 ft. 4 ins. x 33 ft. in the clear, and is concrete-lined throughout, with concrete arched entries at both seams. This shaft is divided by three lines of 8 in. x 12 in. buntons into an air way, two hoist ways, and a pipe way. At the bottom, under the hoist ways, is a sump 8 ft. deep, lined with concrete. Each seam has two 24-ft., three-center concrete arches over the main entries, and a 15-ft. arch over the air course. The lower seam has, in addition, an 8-ft. entry for pipes at one end of the shaft. The plans for the hoist shaft lining required a thickness of 1 ft. at the sides and 1 ft. 6 ins. at the ends. The buntons are held by cast-iron pockets or boxes imbedded in the concrete lining, so designed that the buntons may be readily changed.

Both shafts were sunk simultaneously. Compressed air was used for drilling and electricity for lighting. Three eight-hour shifts, six days a week, were employed. The average weekly progress in the hoist shaft was 16 ft., and 20 ft. was the best week's work. This shaft was 19 ft. 4 ins. x 36 ft. through the rock, and contained 20.2 cu. yds. of rock per lineal ft. The rock penetrated was solid, and, except at the surface, no timbering was required. The sump and the necessary excavation for the arches at the lower seam were completed before any lining concrete was placed.

A mixing board was built between the shaft and the engine house. In the shaft, 4 ft. below this level, a platform large enough to hold two shaft buckets side by side was set on the cross braces (Fig. 1). A paddle mixer was set up on the mixing board, with its spout overhanging this platform, and a movable chute was adjusted so that the concrete could be run into either bucket. When a bucket was filled the chute would be thrown over, the bucket would be hoisted enough to swing clear of the platform, lowered into the shaft and dumped. It was thus possible, by filling one bucket while the other was being emptied, to run the mixer continuously.

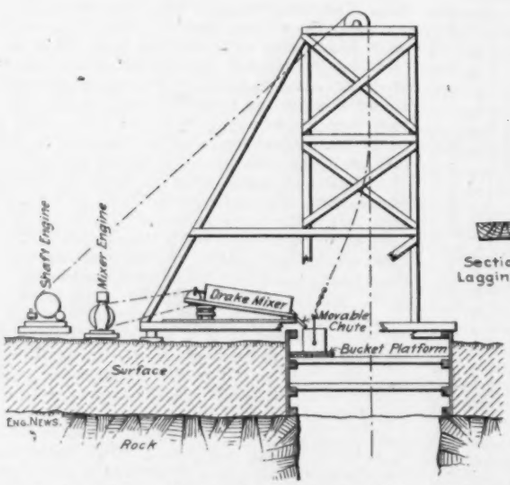


Fig. 1. General Layout of Concrete Plant for Lining Elliptical Shaft.

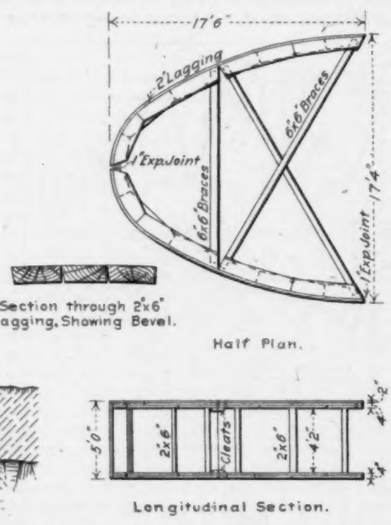


Fig. 2. Movable Form for Concrete Lining for Elliptical Shaft.

The sump lining and the arch bench walls for a distance of 10 ft. back from the shaft at each opening were completed before the arch centers were set. For filling the arches a platform was set about level with their crown. A horizontal elliptical ring of the shape of the cross section of the shaft was set to correspond with the shaft lines 2 ft. above the crown of the side arches. Vertical lagging was run from this to the arch centers all around and the concrete thus brought to a level. The placing of all this concrete was continuous, making the lining of the shaft bottom monolithic.

The forms for the vertical lining were built in 5-ft. rings, each having eight sections. These were constructed of 2 in. x 6 in. vertical lagging, nailed to segments or frames at the top and bottom. The bottom frame of each section was fastened to the upper frame of the section below by two 1½-in. oak dowel pins. The top of the sections were held together by cleats nailed on the joints, and by 6 in. x 6 in. braces bolted to the under side of the upper frames. Spaces were left in between sections at the side joints to facilitate the removal of the forms. The cracks thus left were covered with strips of roofing paper.

Lining was carried on in two shifts, one placing a ring of forms and the other filling it with concrete. A platform was laid on each set of braces for dumping the concrete. As the platform was level with the top of the ring, during the concrete was not laborious. Little ramming was needed, as the concrete was mixed wet. A smooth surface was obtained by working along the narrow spade up and down against the forms.

The cast-iron boxes for the buntons were placed in holes cut through the forms, and were lined and held in place by temporary buntons made of boards.

The arches at the upper seam were put in similarly to those at the lower. The shaft forms below the upper seam were then taken out and used one by one above it. Only ten rings in all were made, and these served for lining the entire shaft. When these ten were all in place again above the upper seam, the lower rings were removed one at a time and used for a third time.

The form shift consisted of an engineer, headman, two carpenters, and two helpers, the latter working either inside or out, as might be required. To set a ring took, on an average, nine hours. The time required to take a ring out from below and re-set it was about the same as that required to set a new ring lowered from above.

The concrete shift consisted of an engineer, headman, about twelve laborers for the mixer and five men in the hole, placing and ramming the concrete. To fill an average ring, containing 30 cu. yds., took ten hours.

The finished lining is generally smooth and watertight, and is a satisfactory job. This work has shown that the most important points which must be observed to make a concrete shaft lining a success are: The forms must be rigid, smooth and practically watertight. They must be built in sections small enough to be readily handled and strong enough to stand rough handling. The cast-iron bunton pockets should be either omitted or modified so that it would not be necessary to cut holes through the forms.

The concrete should be placed wet, and faced by working a perforated shovel or similar instrument next the forms.

Springs delivering any considerable volume of water should be drained to the shaft by a pipe through the concrete. These pipes, if plugged at all, should not be plugged until the concrete has set hard.

Cost of Concrete Shaft Lining for Hoist Shaft, 5.9 cu. yds. Concrete per ft. of Depth.

		Per ft. of depth.		Per cu. yd.	
Stone		5.90		1.00	
Sand		1.77		.30	
Cement		19.18		3.25	
Labor	Mixing	3.83	9.42	.65	1.60
	Placing	3.40		.58	
	Firemen and pumpmen	2.19		.37	
Forms	Lumber, $13 per M	1.83	9.61	.31	1.62
	Making, $21 " "	2.95		.50	
	Placing	4.83		.81	
Platform for starting upper section		.92		.16	
Superintendence		3.03		.51	
Plant		.28		.05	
Oil		.21		.04	
Sundry		1.06		.18	
Tools		.24		.04	
		$51.62		$8.75	

The shafts were designed by Howard N. Eavenson, Chief Engineer, U. S. Coal & Coke Co. The Dravo Contracting Co. of Pittsburgh, Pa., had the contract for the sinking and lining, and the writer was superintendent on the work.

OVER-SPRINKLING ASPHALT STREETS in New York has aroused the Society for the Prevention of Cruelty to Animals, but that organization can find no municipal executive department that will admit responsibility or power to control the private sprinkling association that has a monopoly of street sprinkling in Manhattan.

*812 Lewis Block, Pittsburg, Pa.

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Twenty years ago the Croton Aqueduct tunnel was under construction and was furnishing a great object lesson of the rapidity and cheapness with which rock tunnels could be driven by modern machinery and high explosives. It was this work that led to a prediction by a prominent contractor, which was published in Engineering News and which some among our older readers may perhaps recall. The man in question was quoted as saying that the building of the Croton Aqueduct tunnel meant more to New York City than merely a new conduit for the water supply. "Now that it is known how rapidly and cheaply underground tunnels can be driven," said he, "men will start tunnels in the region above New York City and will drive them southward underneath the whole length of Manhattan Island. Through these tunnels fast express trains will be run, carrying passengers from points in the country directly to their destination in the city." This was the gist of the prediction—we quote from memory only, the article itself having eluded our search—and it has been remarkably fulfilled. A multitude of projects for tunnel passenger transportation beneath New York did spring up, in the years following the Croton Aqueduct completion, and out of them all there finally emerged a project for such a line to be built and controlled by the City of New York itself. Year after year that project was agitated; again and again it met with defeat. For a dozen years active hostility, public indifference and the skepticism of engineers, contractors and capitalists were sufficient to defeat the enterprise, and not until the year 1900 was actual work upon it launched. Its final completion and opening to public traffic on Thursday last, Oct. 27, marks the beginning of the fulfilment of that prediction which we quoted above.

As our older readers can testify, Engineering News has been a strong friend and advocate of the New York Rapid Transit enterprise from its earliest inception. We defended it at a time when its friends were few, when none could be found brave enough to risk investment in it, and when other engineering journals thought it dignified to criticize it or at best withhold their approval. From start to finish we have maintained that the project was a wise one; that it was an absolute necessity to the welfare of the city and its business prosperity; that it was based on sound engineering principles and practice, and that it would amply justify the investment of capital by the city and by private investors. At the present time one must search far to find one who doubts these things, but it was not always so.

In the simple and dignified ceremonies which marked the opening of the line to traffic on Thursday last, very proper recognition was given to the engineers and contractors who have built the tunnel, as represented by Mr. Wm. Barclay Parsons on the one hand and Mr. John B. McDonald on the other. It is, we believe, not too much to say that had either of these men not done what they have done, New York might not have a Rapid Transit railroad to-day. Mr. Parsons has given to the enterprise more than an engineer always or ordinarily gives to a project whose technical responsibilities he carries. He has been its strong defender at every turn, as loyal to it in its darkest days, when its friends were fewest as when success was finally accomplished. Had its engineering details in its many seasons of stress been less skilfully and conservatively planned, less sedulously guarded at every point, less ably represented before courts and commissions, it is quite possible that the enterprise might at some time have actually received the death blow which often seemed perilously near.

As for Mr. McDonald, he risked his fortune and business reputation in bidding for the contract, and he was in all probability the one contractor who could have secured the necessary financial backing to make his bid effective. His experience in driving the B. & O. tunnel under the streets of Baltimore had given him the confidence in his own ability to carry the work to success, and enabled him also to secure the confidence and effective backing of capitalists, where any other contractor, lacking the experience in that class of work and the prestige from success achieved in it, might very likely have failed.

It is true, as we said at the outset, that the successful work on the Croton and other tunnels of the early '80's gave the initial impetus to the projects for underground passenger transit in New York City; but the Rapid Transit road of to-day owes its success as much to another development of the '80's as to the advance in the art of tunneling. The electric light and the electric railway motor are an essential part of the present Rapid Transit road, and had their development been postponed, it is very doubtful whether the underground system of rapid transit now possessed by New York and half a dozen other great cities of the world would be in existence at the present time. The early projects for rapid transit underground railways were generally indefinite as to the motive power to be employed, but cables and compressed air had each strong advocates; for it was not generally appreciated, even by engineers, a dozen years ago how greatly superior to either of these the electric motor was to become. From this point of view the epoch making work of Mr. Frank Sprague in applying electricity to the street railways of Richmond, Va., in 1887, is quite as much to be considered a forerunner of the subway as was the building of the Croton Aqueduct tunnel a year or two earlier.

At the meeting of the Iron & Steel Institute of Great Britain, held in New York last week, various highly scientific papers were presented by learned savants together with one or two other papers discussing matters of a practical nature; but the paper which in human interest far surpassed all others, was a description of the method of iron production practiced by a community of uncivilized natives on the West Coast of Africa. We print the paper on another page of this issue. Its author, Mr. C. V. Bellamy, is a Member of the Institution of Civil Engineers, and holds the office of Director of Public Works for the Colony of Lagos. The story which he tells is one of surpassing interest.

It appears that this community of native Africans has been practicing the art of iron smelting for unknown generations. The community consists of the inhabitants of a small village, numbering barely a hundred, and so far as these people know, they are the only people in that part of West Africa, or for that matter, in the world, who possess a knowledge of the art.

The question which at once arises is how the industry originated among this primitive tribe. Was it a discovery of some remarkable genius among them; or was it taught to them long ago by some wanderer from more civilized lands? All the probabilities would seem to be in favor of the latter supposition, for the art of smelting iron from its ore involves such difficulties that it has rarely originated among any people until they became considerably advanced in civilization.

It is conceivable, indeed, that some chance use of bog iron ore as material to surround an open fire might result in partial smelting of the metal; and that from this discovery some genius might develop a practical process of ore reduction. This has been, doubtless, the manner in which iron smelting originated everywhere. And it is of course possible that it may have been developed here in like manner. On the other hand it must be remembered that Lagos is in equatorial Africa, in a climate where fire is very little used, and the accidental production of iron would be less probable. Even if produced among uncivilized and superstitious people, it would be far more apt to be ascribed to some supernatural influence than seized upon as a discovery of practical value. Among peoples far higher in the scale of civilization and far more advanced in the use of tools, the process of iron production was only brought into being by a slow process of evolution.

The more probable supposition, to our minds, is that some European, sold into slavery, cast away in shipwreck or perhaps a voluntary wanderer in the unknown wastes of equatorial Africa, undertook to teach to a tribe of natives the art of iron production as then practiced. This may have occurred very likely hundreds of years ago, and the art have been passed down from generation to generation till the present day. Possibly the date of its introduction lies still farther back and it may have been some metallurgist from ancient Egypt or Morocco, who carried the knowledge of iron working to these dwellers on the Gulf of Guinea. That the date of introduction lies far back seems probable in view of the fact that these people themselves have no knowledge as to how their forefathers first learned the art. If the introduction had been in recent times their traditions would doubtless record it.

Although it seems probable that these people did not originate the art which they now practice it is still a wonderful fact that they have preserved it and maintained the industry for a period longer than their traditions tell.

When one considers the vicissitudes through which the inhabitants of equatorial Africa have passed in the last two centuries—the internal warfare, the raids of slave hunting parties, the ravages of pestilence—it is indeed a wonder that this little community should so long have been left unmolested to pursue its industry, passing down the requisite skill and knowledge from one generation to the next.

The wonder is, too, that the industry has not perished at some stage through ignorance. When one considers what the civilized man has as aids to his work that these simple children of the forest have not—books which record all progress of the past, tools of every sort, education, organization commerce, knowledge of physics, mathematics, chemistry—one is filled with admiration for the ability displayed and the excellent results obtained by these primitive Africans.

For a year or more past, purchasers of Portland cement have been reaping the benefit of the enormous expansion in the productive capacity of American Portland cement mills which has taken place in recent years. The cement mills have been able to produce more cement than the mar-

ket demanded, they accumulated as large stocks as their storage facilities would permit, and some of them had to suspend operations. Meanwhile, the consumption of cement has been steadily increasing. The applications of cement in the production of reinforced concrete structures, concrete blocks and a multitude of other fields are extending all the time. For some months past the accumulated stocks of cement have been drawn upon and in many cases they have been reduced to very small proportions. Prices for cement have already risen 5 to 10 cts. per barrel, and a farther rise appears probable. The outlook is for a busy year for cement manufacturers, and a period when purchasers of cement will have to be alert to secure the shipments of the material which they order, while engineers will have to be on the watch against cement shipped so soon after manufacture as to be in danger of proving unsound in the work.

That prices will be permanently restored to the level prevailing a few years ago, however, does not appear at all probable. The great producers of Portland cement are working at so low a cost that there is a good profit for them even when the selling price is at a point which would a few years ago have been deemed extraordinarily low. If the demand for cement warrants it, there are a number of large producers who are ready to enlarge their plants. As the ordinary unit for a cement plant is now a thousand barrels a day, additions of such units to only a few plants means an enormous increase in the total productive capacity of the country.

LIVE LOADS ON FLOORS.

Two weeks ago Mr. C. C. Schneider presented before the American Society of Civil Engineers a general specification for structural steelwork of city buildings, together with a brief discussion of his points of dissent from general practice. Among the novel features of this specification is the scale of live loads for floors which the author recommends. He asserts that any floor construction should be proportioned for two alternative contingencies: (a) the highest probable distributed load, and (b) the highest probable concentrated load, at any or a specified point. This second loading in practice may be of two kinds: either a point-load or a line-load, that is to say, either a single concentrated load at any point or a load concentrated on a narrow strip covering the girders or primary floorbeams. The scale of loads recommended is as follows:

	Alternative Live Loads, in Pounds.		
	Distributed Load.	Concentrated Load.	Load per lin. ft. of girder.
1. Dwellings, hotels and apartment houses	40	2,000	500
2. Office buildings	40	5,000	1,000
3. Assembly-rooms with fixed seats, like theatres, churches, schools, etc.	40	5,000	1,000
4. Assembly-rooms without fixed seats, like ballrooms, gymnasia, armories, etc.	80	5,000	1,000
5. Stables and carriage-houses	70	5,000	1,000
6. Ordinary stores and light manufacturing	40	8,000	1,000
7. Sidewalks in front of buildings	100	10,000	.....
8. Warehouses and factories	from 120 up.	Special	Special
9. Charging floors for foundries	from 300 up.	Special	Special
10. Power-houses for uncovered floors	from 200 up.	The actual weights of engines, boilers, stacks, etc., shall be used, but in no case less than 200 lbs. per sq. ft.	

It is a fact that the loads to which floors are actually subjected should, from the designer's point of view, be thus classified as distributed and concentrated loads. The relations between their respective effects vary with the area of floor supported and the span. While it is possible, with given concentrated loads, to select a distributed loading which will equal or exceed the maximum effects of the concentrated loads, yet in any other case, where area and span are different, or even in another part of the same floor-panel, this equivalent distributed load would have to be differently chosen. Such a procedure is more irrational, confusing, and wasteful of time than the double calculation for both classes of loading. In bridge work, and, indeed, in all structural steel work involving mainly live-loads, it has long since become universal custom to compute separately the effects of the various possible kinds of loading and sum their most severe effects in a given member as the basis for proportioning the member. The same practice should find its way into building work generally. Mr. Schneider's scale of live-loads deserves approbation because it specifies, almost for the first time, that floors must be designed to stand a suitable concentrated loading as well as a distributed load. It will have done its duty if it leads to the recognition of concentrated loads in those specifications which, above all others, should prescribe carefully-chosen loadings for designing buildings—public building laws.

While agreeing with Mr. Schneider in the principle of recognizing concentrated as well as distributed loads in building calculations, we cannot agree with him in the actual loads which he specifies. His distributed loadings for floors are far below those which may occur, and are therefore too low, in our opinion, as designed loadings. This criticism applies solely to Classes 1 to 8 in the above-quoted table, that is, to those cases where the structure is exposed to a distributed loading due to people massing upon it, rather than to loads resulting from stored material. In the latter case, of course, the loading to be used in the design depends upon the conditions of the individual case, and for the same kind of building it may be necessary, in the building law of a given city, to specify a higher loading than is used in some other locality. But crowds of people do not vary in their characteristics from place to place, and they are much alike when they invade a dwelling or an office and when they crowd a political meeting hall. It is possible to set down a loading which will apply to all cases, making perhaps a percentage addition for cases where the crowds are apt to be very lively or to move in unison—meeting halls, armories or ball-rooms. On this account, also, it is possible to criticize Mr. Schneider's scale of distributed loads, without reference to any particular case.

No argument is required to support the statement that in designing structures we should plan for the most unfavorable conditions of loading which can be foreseen. This practice is almost universal in structural designing; indeed, an evasion of it is at once stigmatized as an effort to "skin" the design, to secure business by jeopardizing the security of the structure. If this principle governs the planning of structures which must support mere dead material, structures whose failure would likely not involve injury to persons, how much more stringently should it control the design of a structure where the extreme conditions of loading are precisely those which would lead to the greatest loss of life! A certain floor, for example, may have smaller chances of experiencing the load of a maximum crowd of people than has a coal-bunker of experiencing its most unfavorable loading, but in the former case a collapse is far more disastrous, and safety therefore should engage the greater consideration.

Some careful experiments on the maximum weight of crowds of people were reported by Prof. L. J. Johnson in Engineering News of April 14, 1904. These gave weights up to 157 lbs. per sq. ft., with the suggestion that a weight of 160 lbs. might be reached in an absolutely compacted stationary crowd. To amplify the evidence on the subject, we have abstracted from a German contemporary the report of similar tests made in Germany, and reprint the abstract in this issue. The German tests showed weights up to 145 lbs. per sq. ft., with a degree of crowding that still allowed motion within the mass. Few people have not experienced a degree of crowding where the interior of the mass was compacted to absolute standstill. And judging by the German as well as the American experiments, this may give a loading exceeding 150 lbs. per sq. ft.

On what grounds, then, are we justified in using a loading of 40 lbs. per sq. ft., such as Mr. Schneider prescribes for dwellings, hotels, apartment houses, office buildings, theaters, churches, schools, stores, and light manufacturing establishments? That dense crowding does occur, by no means as an exceptional occurrence, the case of theaters, churches, and the like, is known to all. That it may occur in hotels, in apartment houses, and even in private dwellings, is equally evident, though it is recognized as being less frequent and for a given case less probable. We are not accustomed to designing for average or probable loads; on the contrary, we cannot in good conscience plan for anything less than the greatest loading which the conditions of the case make possible. It would be curious engineering were we to design the framework of an apartment house on the basis of average loading, or were we to neglect the higher loading that would occur only once in a year, or once in five years, or once in ten years. Do we build apartment houses to fail once in ten years?

The author's *expressed* argument for this scale of loads is brief and unsatisfactory, and need not be gone into at present; it is based on a single statement covering a few chance observations, which are mere negative testimony in the present discussion. But if we inquire what grounds may have led the author to be satisfied with his ultra-low loadings, we may find two explanations; first, he assumed that the distributed load is of little importance since ordinarily the concentrated loads would predominate in effect, or second, he relied upon the mysterious margin of the factor of safety. These reasons need no lengthy discussion here to controvert them, but may be left to stand on their merits. For our part, if, as a matter of approximating actual conditions, we are to classify loads as distributed and concentrated, we should wish to select the design load in each class as near as possible to actual maximum. And if we use a given factor of safety in a design, to cover *unknown* and largely unknowable dangers from variations in assumed conditions, we should preferably not encroach upon that margin by a neglect of *known* dangers. It is to be borne in mind that the actual possible loading of 150 lbs. per sq. ft. is nearly four times as great as Mr. Schneider's specification of 40 lbs.

THE SUPPRESSION OF TYPHOID FEVER AT ITS SOURCE.

The fight against typhoid fever has been well begun in the United States through the efforts already made or in progress to improve the quality of public water supplies by filtration and other means. The next step should be to attack the danger at its source. In other words, vigorous measures should be taken to suppress or render innocuous the rural privies which now menace the water and milk supplies, and to a lesser extent some of the other food supplies of the country. Speaking of this subject primarily with reference to New York City, the "Medical Record" (New York) of Oct. 15, says:

> New York City is passing through its annual visitation of typhoid fever in rather more aggravated form than usual this autumn. The large morbidity and mortality figures for typhoid fever presented in the weekly report of the health department have served to direct public attention to the prevalence of the disease, but except that the figures are a little larger than usual, there is nothing peculiar in the present autumnal epidemic. We have it every year—this "vacation typhoid," and it is the penalty we pay for our foolish trust in "the old oaken bucket." We go to the woods and the mountains asking for health and we get disease. This is the chief source of our typhoid fever, the importation of the bacillus in the bodies of its victims, but there is doubtless some brought in with milk and salads. In whatever way it comes, however, it comes from the country, and is never city bred. This is as true of every city as it is of New York, hence if we would do away with typhoid fever we must initiate the work of sanitation in the country. The filtration of the water supply is an excellent safeguard, and expensive as it is, it would well repay every city to install a filtration plant; the boiling of water will undoubtedly kill all the contained microbes—the good with the bad unfortunately—but if this method is to be effectual all the water, that for bathing and dishwashing as well as for drinking, must be treated; but when all this has been done our salads and other vegetables eaten raw may carry infection, and milk cans and bottles may be washed in infected water or the milk may be diluted with it. We are then at the mercy of the country, and we must demand of the country a sanitary reform.

The "Medical Record" then refers approvingly to a paper by Dr. Wm. C. Daggett, of New Haven, Conn., read in May, 1904, before the Connecticut Medical Society, and since printed for circulation by the Connecticut State Board of Health (New Haven, Conn.). Dr. Daggett insists upon "the rural

gin of urban typhoid fever," which is in the ntry privy, the location and construction of which are, o often than not, faulty, and which is in consequence potential focus of an epidemic of typhoid fever, either the immediate neighborhood, or, more probably, in distant town the water supply of which is drawn from the water shed which this privy pollutes.

As a safeguard, Dr. Daggett suggests a permanent board of State sanitary inspectors, each member to be a competent civil engineer. The board would locate privy vaults in reference to public water supplies, would have power to condemn and relocate wells, and would make suggestions as to the prevention of the breeding of flies and the dissemination by those insects of the typhoid and other dangerous intestinal bacteria.

Even if it should prove impracticable to conduct the fight against typhoid fever on so comprehensive a plan as Dr. Daggett suggests, as for years to come it doubtless will be in many of the States of the Union, there is no reason why work of the same general character should not proceed from many local centers. Every progressive water board and water company, backed by the corresponding local board of health should enter upon a campaign of protection of its sources of water supply, and every local board of health should conduct a no less vigorous campaign for the protection of its milk supply. If every house privy which might be the means of contaminating either a public water or milk supply were put beyond any such possibility, the effect upon the typhoid fever mortality of our cities and villages would be marvelous. At the same time the number of privies dangerous to the rural population and also to city visitors in rural districts would be greatly decreased.

Another preventive measure in the interest of urban populations would be to require a State license for all householders who take summer boarders. Such licenses might be issued by state boards of health, acting, in some cases, through local or semi-local agents.

We cannot close without calling attention to the fact that none of the suggestions thus far made go clear to the root of the evil. There can be no safety until physicians, nurses and householders cooperate in the proper handling of typhoid patients, their bed and other clothing and their dejecta. Nurses, whether members of the family or otherwise, must not, when it can be avoided, attend to patients and at the same time cook and do other work for the family at large. Clothing and bedding used by typhoid patients must be destroyed or disinfected. Dejecta must also be disinfected, even where houses are connected with the sewers. And the disinfection must not be of the sham kind so common even now on the part of supposedly intelligent and certainly well-meaning doctors and nurses. Obviously the safeguards just indicated cannot be established under private initiative among the poor and ignorant classes of the population. For them, much of the work and cost will fall upon local or State health departments. It should be noted that this partioular line of work is essential in city as well as country. For its performance some patients will have to be cared for at public expense in their homes and others in hospitals. Hundreds of dollars are spent in communities small and large for each single case of smallpox, and yet the disease is far less dangerous than and claims few victims compared with typhoid fever. With intelligent effort we may yet reduce typhoid fever to as low a yearly total mortality as smallpox, but a vast amount of both rural and urban sanitary reform must be effected before so happy a result is attained.

LETTERS TO THE EDITOR.

Low's Formula for Masonry Arches.

Sir: I have used Mr. Emile Low's formula for thickness of stone arch keystones for several years with satisfaction, and I wish to say a word in its favor in the discussion now going on in your columns.

The diagram given by Prof. Cain in your issue of Oct. 20, 1904, shows that Low's formula calls for less thickness of key than any other formula quoted, unless it be Trautwine's. This may lead some to distrust it; but the table given by Low in your issue of Sept. 15 shows that many important arches have a less thickness than his rule calls for.

Prof. Cain speaks of stone of "medium resistance not so hard as granite." He states also that his curve is for railroad bridges. The line representing Low's formula is for H = 0, that is zero surcharge at center. Now in figuring arches to carry railroad tracks my practice is to add about 15 ft. to the actual surcharge to allow for weight of train. I understand also that Low's formula applies to granite with joints filled with Portland cement mortar.

When using uncut stone with wide joints in the back filled with rubble work I allow only 75 to 80% of full value for such filling. For stone of "medium resistance" similar allowance should be made. If corrections are made for these features the line representing Low's formula will be brought up among the rest shown, but it will not then be so high as Cain's.

Ordinary arch bridges do not depend wholly on the ring for stability. The spandrel filling is good masonry and can be counted upon to resist distortion with the ring although the bond is generally not all that it should be.

I think it a mistake to build an arch ring deep enough so that the line of centers of pressure will keep everywhere within the middle third, if spandrel filling of the ordinary character is to be built.

A uniform depth of arch ring is more economical than one that varies, and if we have a depth that is ample for the pressure at the crown the requisite additional thickness towards the spring line can best be made by the spandrel filling. Yours truly,

J. P. Snow.

Boston, Mass., Oct. 25, 1904.

Sir: Referring to Professor Cain's communication in your issue of Oct. 20, 1904, criticizing my formula $[d = \frac{1}{8}\sqrt{10\ (S - R) + 2\ H}]$ for the depth of arch ring at the crown for masonry arches, he fears that the formula does not give sufficient depth for a railroad bridge, carrying the enormous locomotives and train loads of today, and that even the excessive depths derived from his theoretical investigations should undoubtedly be increased in certain cases.

In order to show how unfounded his fears are, I would respectfully call attention to the double 140-ft. span stone arch bridge carrying the Fitchburg Railroad over the Connecticut River at Bellows Falls, Vt. This bridge is fully described and illustrated on page 402 of the June 21, 1900, number of Engineering News. It consists of two arches, each of 140 ft. span and 20 ft. rise, or Rise ÷ Span = 1 — 7. Each arch ring contains 72 courses, 4 ft. thick. The span of these arches is certainly the longest of any stone masonry railroad bridge in the United States, and that it carries as heavy a load as any cannot be gainsaid. My formula, with surchage H = 0, gives a crown depth of 4.33 ft., or .33 ft. more than the actual depth of ring stone of the bridge in question. Respectfully,

Emile Low, M. Am. Soc. C. E.

Utica, N. Y., 33 Mann Bldg., Oct. 29, 1904.

Outlining Title Lettering by Means of Type and Finishing the Letters in the Ordinary Way.

Sir: In casting about for some rapid way of lettering titles on drawings, I noticed a recommendation, in your columns of a year or more ago, to print the titles on the drawings with suitable type in a regular job press.

While this would seem to be good practice in those large offices where an immense number of drawings and tracings is turned out, it would hardly be justifiable in smaller offices where the bulk of work would be too small to justify the outlay, and yet is large enough to be an annoying source of expense.

In this connection, a plan has been experimented with by the writer which may possibly prove of interest to those of your readers who have experienced the same troubles. The writer provided himself with several sizes of rubber type; not the regular "stamping outfits" of interchangeable type, but those sets now so common for printing notices, known as "rubber printers." A grooved straight edge is provided as a guide to alinement of the letters, and a small wooden gage slides along this groove to regulate the spacing.

The type are blocks of wood with the letters cast in rubber on the printing face, and with a suitable handle, on which each letter is labeled, to prevent mistake. The letters are printed, one by one, by a slight pressure of the hand, the gage being slid along the guide a proper distance each time.

The ink furnished with such outfits is in no way suitable for the formation of perfect letters: that is, letters which will be of uniform blackness over their entire surface, and clear cut around the edges. For this reason no effort is made to print them in "full ink," but just enough ink is used to give a faint but sufficiently clear outline of the letters. These are rapidly filled in by hand. The advantages to be gained by this system are:

(1) The great rapidity with which titles may be made up in alinement and position along the lines.

(2) The ease and grace of some styles of letters now furnished, as opposed to the rigor of the "block letter," and the difficulty which those unaccustomed to it experience in reading it.

Possibly an ink might be prepared which would enable the stamping to be done complete, in one act. The filling in required in the present use of this system takes no more time than the filling in of black letters, while the stamping takes probably not over one-fiftieth the time and effort required to design and form block letters. I am convinced that the work may be done with equal finish.

Thus, with an outfit costing from two to three dollars, the engineer may get up attractive lettering at a cost very small, both in time and effort, as compared with the regular system now in use.

Very truly yours,

J. N. Ambler, City Engineer.

Salem, Va., Oct. 14, 1904.

A Septic Tank Quandary.

Sir: Can you or any of your readers enlighten me with regard to the following question: A septic tank designed to provide for future increase in population and in use of the sewers is to be put in operation while the quantity of sewage reaching it is so small as compared with its capacity that it will take several days, or possibly weeks, for it to fill to the level of the river over which the effluent is to flow. Is it better in such a case to let the sewage remain in the tank so much longer than it should to obtain the best results from the septic action, or should it be partly filled with water before admitting the sewage? Which is the greater evil, retention of the sewage for too long a period or excessive dilution?

Yours truly, Frederick M. Thomas,
Chief Engineer Sewer Commission.

Skaneateles, N. Y., Oct. 24, 1904.

(A better plan than either, if practicable without too much expense, would be to divide the tank into two compartments. One size could then be used until both are needed, and the second would always be of service when the tank required cleaning. If the tank is already built, possibly a temporary plank partition could be erected, so placed as to utilize only a small part of the width of the tank at the outset. Or, if the inlets and outlets permit, or can be temporarily adjusted, the temporary partition might be built across one end of the tank, thus economizing material and labor.

Assuming, as our correspondent does, that the tank is to be used without division, some of the engineers, chemists and bacteriologists who have operated septic tanks might answer his question better than we. It may be said, however, that once the tank is filled, probably it would not matter much, or at least long, whether it had been filled with sewage or with sewage and water, since each future day's flow of sewage would remain in the tank far longer than is compatible with the best results from septic action.

To our mind, the real problem is not fully stated, although the question as put is perfectly fair. A full statement of the problem would include: (1) Location of tank in relation to inhabited areas, whether covered or open, and whether the sludge can be removed without drawing off the sewage. (2) Method of treatment, if any, of the septic tank effluent. (3) Character and volume of the water into which the final effluent is discharged, nature of country through which the stream flows, and uses to which the water is put.

It is conceivable that more of a nuisance might be created by using the septic tank while the sewage flow is very small than by letting it flow away untreated. This might be the case whether or not the septic tank effluent was filtered, and would be quite likely in case it was applied to a filter by means of sprinklers. If filter beds are to be used it might be feasible to rely upon them alone, until the volume of sewage increases, since the capacity of the filters, like that of the septic tank, would at the outset be in excess of the sewage flow, and might be ample to treat all the sewage during the first few months after the sewerage system is put in operation.—Ed.)

Bids for a Bascule Bridge for the Chicago & Alton R. R.

Sir: Referring to the Engineering News of Oct. 27, 1904 (page 293, Construction News Supplement), under the heading "Bridges," Chicago, Ill., we note the following:

Bids for bascule drawbridge on the joint track elevation work were received by Chicago & Alton R. R. Co. as follows: Scherzer Rolling Lift Bridge Co., $135,000; Page & Shnable (Page bridge) $153,000; Roemheld & Gallery (Strauss bridge), $134,000.

This statement is not true, as far as the bid on the Scherzer bridge is concerned. The bid submitted on the Scherzer bridge was less than the lowest sum above mentioned and covered the Scherzer bridge complete in

every detail. The figures, as published in Engineering News, are injurious to us and would do us much greater injury if not denied. They were evidently furnished with the intent to influence pending contracts; therefore we would respectfully ask that you kindly give equal and early publicity to our statement.

Yours very respectfully,
The Scherzer Rolling Lift Bridge Co.,
By Theo. Kandeler, Consulting Engineer.
1616 Monadnock Block, Chicago, Ill., Oct. 29, 1904.

(The above letter explains itself, and it only remains for us to add that the figures were published by us in good faith, having been furnished from a source which we regarded as reliable, but which was evidently misinformed. It will, of course, be understood that we cannot undertake to personally verify the prices of the numerous bids which are sent in to us, although great care is exercised in regard to information of this kind. —Ed.)

Notes and Queries.

The inventor of the steel form for concrete sewer construction, described on p. 350 of our issue of Oct. 20, is Mr. Jacob B. Blaw, of Atlantic City, N. J., and not Mr. Thos. A. Burrows as stated.

In the article on the ditching dredge at Council Bluffs in our issue of Oct. 27 (p. 382) there were two typographical errors: The height of the boiler should be 9 ft. instead of 90 ft. (1st col., 3d line from bottom); the work being done in September should be 70 yds. per hour instead of per day (3d col., 7th line from bottom).

By a slip of the pen, "Hanover College" was written for Dartmouth College in the article on the use of copper sulphate in a reservoir at Hanover, N. H., in our issue of Oct. 27.

EXPERIMENTS ON THE WEIGHT OF CROWDS.

Some interesting matter on the floor loads which may be produced by crowds of people was given in Engineering News of April 14, 1904, by Professor L. J. Johnson, who made some careful experiments, and showed that the usual assumptions as to maximum floor loads from crowds are quite erroneous. Stimulated by Professor Johnson's results, Mr. Hunscheidt, of Bonn, Germany, has recently made some quite similar tests, and reports them in the "Centralblatt der Bauverwaltung" of Oct. 8. These tests gave results which are in general quite confirmatory of Professor Johnson's conclusions; that is to say, the weight of crowds per square foot of floor area is much larger than designers generally assume; it may easily reach 125 lbs. per sq. ft. and at times, in very dense crowding, may be as high as 150 lbs., or even higher.

The German tests, briefly summarized, are as follows:

Test 1. Test area, 5.4 ft. × 10.2 ft. Area, 55 sq. ft. Loading, 40 firemen, age 25 to 45 years; average weight, 158 lbs. These 40 men filled the test area so that they just touched each other without any crowding. Average head, 116 lbs. per sq. ft.

Test 2. Six firemen added to the 40 of the preceding test. Total, 46 men of 158 lbs. average weight. Slight crowding, "about equivalent to that frequently observed on a crowded street-crossing, or in a crowd leaving an assembly hall or church." Average load, 133 lbs. per sq. ft.

Test 3. Four men added to the 46 of the preceding test. Total, 50 men of 158 lbs. average weight. Dense crowding, "as in a large crowd in a narrow street, or on landing bridges, or at Christmas time in the entrance of a large store." Average load, 144 lbs. per sq. ft.

Test 4. Test area, a light court enclosed by walls on three sides and closed off by a board on the fourth side. Dimensions, 4.9 × 5.25 ft. Area, 25.8 sq. ft. Loading, 25 schoolboys; age, 14 to 18; average weight, 111 lbs. Condition of crowding about as in Test 1. Average load, 108 lbs. per sq. ft.

Test 5. Three boys added to the 25 of the preceding test. Total, 28 persons of 111 lbs. average weight. Test space fairly well filled. Average load, 120 lbs. per sq. ft.

Test 6. Two boys added to the preceding 28, making a total of 30 of average weight 111 lbs. Dense crowding, about corresponding to the conditions of Test 3. Average load, 129 lbs. per sq. ft.

The average of the loadings found in the above tests was 126 lbs. per sq. ft., the minimum 108 and the maximum 144 lbs. per sq. ft. The high unit loading reached by Professor Johnson (157 lbs. per sq. ft.) was not attained. But the above-cited tests 3 and 6 seem to represent crowds still permitting one to move through them, though with some effort. Professor Johnson pushed the crowding to a point where the crowd was compacted enough to prevent an individual within from moving through it. This probably explains the difference in results.

Mr. Hunscheidt considers his tests to prove that the loading of 82 to 102 lbs. per sq. ft. usually assumed in Germany in floor-design, and prescribed by the Ministry of Public Works for this purpose, is far too low to allow for conditions that may frequently occur. This figure should be raised to at least 123 to 133 lbs. per sq. ft., he concludes; otherwise the assumed factor of safety may be encroached upon materially.

REGULATIONS FOR THE UNIVERSAL WATER METER SYSTEM AT MERRIMAC, MASS.

The universal water meter system has been introduced by Mr. Freeman C. Coffin, M. Am. Soc. C. E., as a part of several new water-works which have recently been built under his direction. This commendable practice demands careful financial planning to avoid heavy deficits in revenue during the early days of the works when the consumers are literally few and far between. At Merrimac, Mass., where the system was recently installed, the minimum yearly meter rates are on a sliding scale corresponding, to a certain extent, with the number of fixtures in use. That is, a minimum charge of $6 a year, regardless of the quantity used, entitles the consumer to draw water at as many points as he chooses, except for water closets, bath tubs and hose. An additional charge of $5 entitles the consumer to as many water closets and urinals as he chooses to install. Another charge ($4) gives the same privilege as to bath tubs, and still another ($5) as to hose, including with the latter "sprinklers, fountains and troughs."

The total of these charges is $20, which is the yearly minimum for "one family or consumer." The proper minimum charge is payable quarterly in advance. At the close of each quarter the meters are read and if the registered quantity, at the established unit rate, is below the minimum charge already paid, no bills are rendered; if in excess, bills are rendered accordingly.

All water meters are bought, set and repaired by the water department, except that repairs made necessary by freezing or through the carelessness of consumers must be paid for by the consumer.

The universal meter rates at Merrimac are as follows: For a rate of consumption of 10,000 cu. ft. per year, 25 cts. per 100 cu. ft.; for more than 10,000 and less than 20,000 cu. ft. annually, 20 cts.; for more than 20,000 and less than 50,000 cu. ft., 15 cts. per 100 cu. ft.

The town furnishes and lays service pipes from the street mains to or through the cellar walls and provides and sets stop and waste valves on the end of the services. The owners of premises are required to pay for the portion of the service beyond the street line and for the stop and waste valve, including both material and labor.

It will be seen that the minimum charges at Merrimac are about the same as the ordinary fixture charges prevailing in many cities. In some instances, particularly under municipal ownership, the fixture charges are lower than the minimum meter charges at Merrimac, but as a partial offset the Merrimac charges permit an unlimited number of fixtures of each of the specified classes, while for $20 a year no limit is placed on the character or number of fixtures.

Customers having no water closets, bath tubs or hose, and thus paying $6 a year, are entitled to 2,400 cu. ft. per year at the minimum rate, or about 50 gallons a day per family. Going to the other extreme of the minimum yearly charge, a payment of $20 entitles a consumer to use 8,000 cu. ft. per year, or 165 gallons a day per family.

If the Merrimac schedule of meter and minimum yearly rates seem to bear heavily on the consumers, it should be remembered that Merrimac is a small place and that in the early days of any new water-works system the rates, by whatever method determined, must be relatively high or else fail to meet the capital charges and operating expenses.

A TRACK-LAYING RECORD of 9,320 ft. in one day has been made on the San Pedro, Los Angeles & Salt Lake Ry. This is a good record, but does not come up to the record on the Canadian Pacific Ry. in 1882, when the average for six months was 2.47 miles per working day, the monthly averages being from 1.47 to 3.22 miles per working day. On the Minneapolis, St. Paul & Sault Ste. Marie Ry. extension across North Dakota in 1893, the average was 3 miles per day, while the regular force on one or two occasions laid over 4 miles of track in 10 hours.

THE LACKAWANNA TUNNEL R. R. CO. has been incorporated by President Truesdale and other officers of the Delaware, Lackawanna & Western R. R. to build a railway tunnel underneath the Hudson River at New York City. While it is possible that the Lackawanna may sometime decide to follow the example of the Pennsylvania R. R. and establish a passenger terminal on Manhattan Island, actual construction of such a terminal and tunnel does not seem probable in the near future. The Lackawanna probably intends merely to prevent some other corporation from stepping in and preempting the right of way which it may possibly at some future date desire to use.

SLATE AS A MATERIAL FOR FIRST CONTACT beds has been recommended by the sewage committee of the town council of Devizes, England. The scheme is the result of experimental work carried on at Devizes for nine months by Mr. W. J. Dibdin, originator of the contact beds bearing his name. The sewage at Devizes is described as unusually foul, containing liquid and solid refuse from tanneries, breweries and slaughter houses. Waste slate will be used, laid flatwise on slate blocks, thus providing a large percentage of air space. Mr. Dibdin has taken out patents for his modification of contact beds, under the name of "multiple surface bacteria beds" (British patent No. 16,851; 1903).

A DISASTROUS COAL MINE EXPLOSION occurred at Tercio, Colo., on Oct. 28. Some fifty or sixty men were in the mine at the time; there is no likelihood that any of them will be found alive. The explosion was in Mine No. 3 of the Rocky Mountain Fuel & Iron Co.

A GRAIN ELEVATOR COLLAPSED at Buffalo, N. Y., on Oct. 30. It was known as the Ontario Elevator, and was of the old-style cribbed timber bin construction. The elevator contained nearly 400,000 bushels of barley at the time of the fall, and much of this grain went into the waters of an adjoining slip. The collapse is thought to be chargeable to weakening of the foundation-piling by dredging a nearby slip.

ANOTHER WRECK DUE TO WORLD'S FAIR TRAFFIC occurred on the Missouri Pacific Ry. at Tipton, Mo., on Oct. 30. A westbound passenger train, going from St. Louis to Kansas City, Mo., was running in two sections; at Tipton Station the first section was taking on passengers when the second section ran into its rear. Three persons were killed, the two rear sleepers of the first section being crushed. The engine-runner of the second section claims that a headlight in the yard made it impossible for him to see the first section, and that his orders were for clear track. The coroner's inquest resulted in a verdict blaming the flagman of the first section and the engine-runner of the second section for the accident.

THE PRODUCTION OF PORTLAND CEMENT in the United States during the year 1903, was 22,342,973 barrels, according to the report recently issued by the U. S. Geological Survey. There were also produced during the same time, 7,030,271 barrels of natural cement and 525,896 barrels of slag cement, making a total production of 29,899,140 barrels of hydraulic cement, valued at $31,931,341. The report states that the increased production of Portland cement in 1903, resulted in a glutted market, and a consequent fall in price. Altogether 19 states contributed to the Portland cement production of the year, but five of these contributed nearly 75% of the total, as shown by the following table:

State	No. Works.	Barrel	Per cent
New York	12	1,602,946	7.2
Pennsylvania	13	9,631,541	43.1
New Jersey	3	2,693,381	12.1
Ohio	8	729,519	3.3
Michigan	13	1,955,183	8.7
All other states	29	5,730,403	25.6
Total	78	22,342,973	100.

The total consumption of Portland cement in the United States in 1903 was 24,309,479 barrels, some 2,251,969 barrels being imported and 285,463 barrels being exported to make this net amount. At present, therefore, 91.9% of the total consumption is supplied by American factories.

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